Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

2023 Research, Development and Technology Forum

November 28, 2023

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

2023 Research, Development and Technology Forum

Yolanda Y. Braxton

November 28, 2023

PHMSA Mission

To facilitate the safe transportation of energy products and other hazardous materials that are essential to our daily lives.

OHMS Background

3.3 Billion Tons of Hazardous Materials Shipped Annually

1.2 Million Hazardous Materials Shipments per Day

Intermodal Partners with FAA, FRA, FMCSA, and USCG

International Role in the UN, IMO, and ICAO

Operation Systems Division

Yolanda Y. Braxton
(Director, PHH-60)

- **Data, Risk, & Analytics** (PHH-61)
- **Program Management** (PHH-62)
- **Research, Development, & Technology** (PHH-63)

DOT Strategic Goals

OHMS Research Focus Areas

- Risk Management and Mitigation
- Packaging Integrity
- Emerging Technology
- Technical Analysis to Aid Risk Assessment

Strategic Goal Alignment

Risk Management & Mitigation

Emerging Technology

Packaging Integrity

Technical Analysis to Aid Risk Assessment

OHMS RD&T- Research Programs

Small Business Innovation Research (SBIR) Program

Supports scientific excellence and technological innovation through the investment of Federal research funds in American small businesses

Directed by DOT's Volpe National Transportation Center

SBIR · STTR
America's Seed Fund™
POWERED BY SBA

Interagency Agreements

Collaborating with our federal partners across the federal government

Research under these agreements foster relationships with other agencies and avoids redundant research efforts.

Broad Agency Announcement (BAA) Program

Competitive solicitation procedure used to obtain proposals for basic and applied research

Research solicited under a BAA attempts to increase knowledge in science and/or advance the state of the art

SAM.GOV®

OHMS RD&T Program Update

Lithium-ion Research Categorization and Analysis

Review the scope and results of Department of Transportation’s lithium-ion battery research projects documented in Department’s repository and Open Science Access Portal (ROSAP)

1. Identify what research documentation exists in ROSA-P
2. Understand the relevance, depth, scope, and results of documented research projects
3. Identify where gaps in documented LiB research (housed in ROSA-P) exist

OHMS RD&T Program Update

RD&T Strategic Communication Plan

Building a strategic plan to increase our engagement with stakeholders to increase collaboration efforts.

Goal #1 Transparency

Increase transparency between program and stakeholders by providing information in a timely matter.

Goal #2 Research Partnership

Seek, strengthen and maintain collaboration efforts with existing and new research partners.

Goal #3 Utilization of Research

Increase stakeholder awareness and utilization of completed OHMS Research.

OHMS RD&T Program Update

RD&T Project Evaluation Framework

Develop a framework to be used to assess the effectiveness, value, and performance of RD&T projects throughout the project lifecycle.

Initial → **Planning Review** → **Checkpoint** → **Project Completion**

OHMS RD&T Program Update

RD&T Program Management App

- Centralized Project Management Tool
- Centralized Document Repository
- Project Analytics for Data Calls
- Tracks Program's Budget and Invoicing

OHMS RD&T

Questions?

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

E-HazID − Integrated RFID, Sensing & Communication System for Safe Transportation of HAZMAT

November 28, 2023

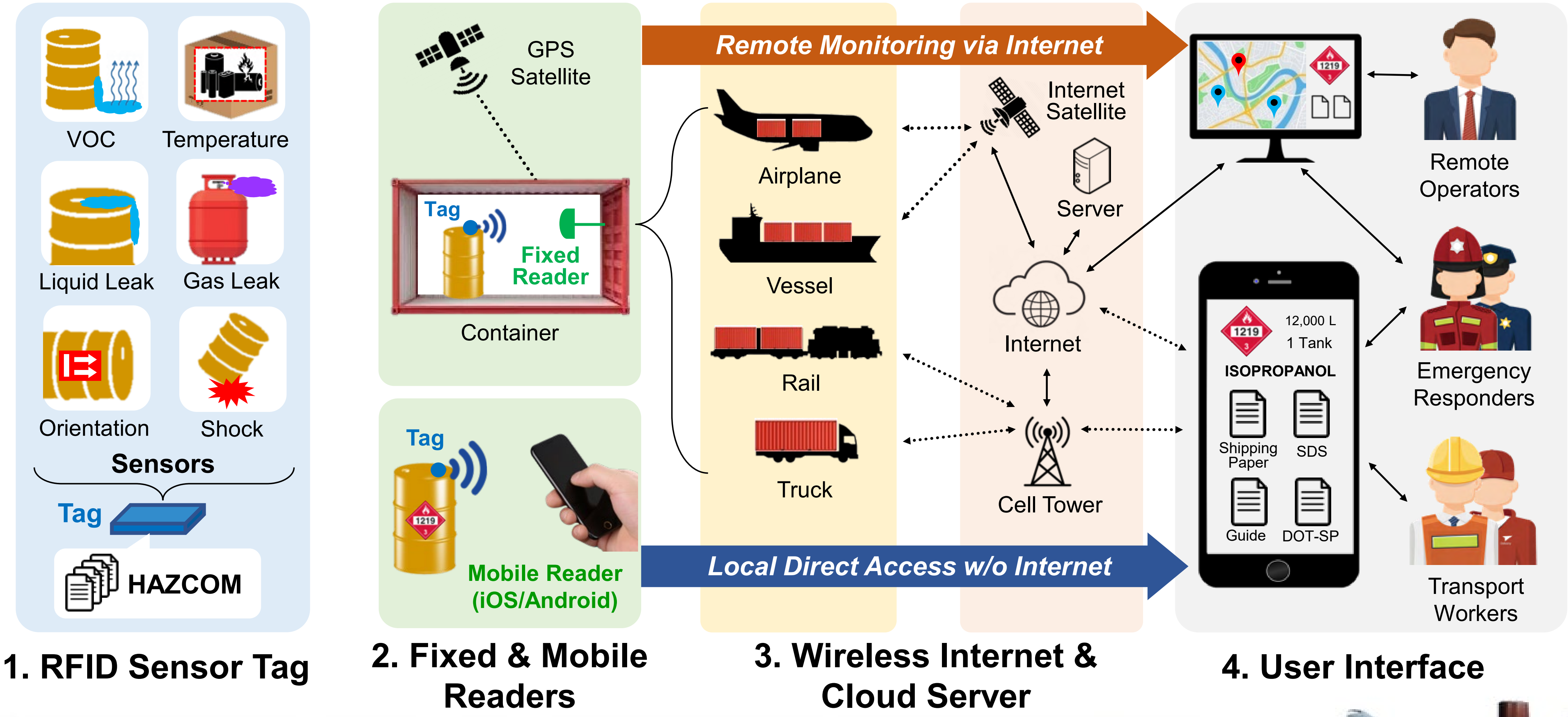
Need for Accurate ID & Monitoring of Hazmat in Transit

- Continuous monitoring of hazmat during transportation is crucial

- Inaccurate or damaged physical labels can hinder emergency response

https://www.hazmatuniversity.com/news/blog-marking-and-labeling-hazmat-labels/

E-HazID for Electronic HazCom & Safety Monitoring

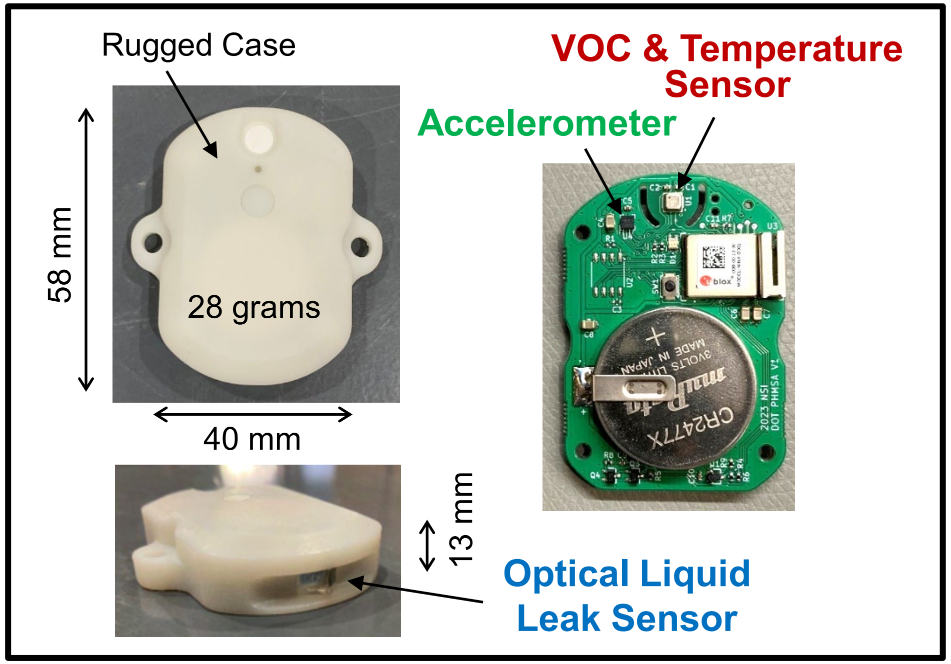


SBIR Phase I Research Objectives

Develop key E-HazID technologies & experimentally demonstrate their feasibility

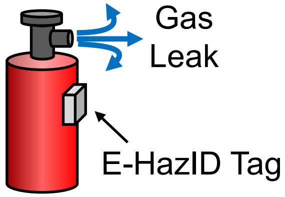
Wireless E-HazID/Sensor Tag | **Mobile App** | **Fixed Reader**

Phase I Accomplishments: E-HazID Tag

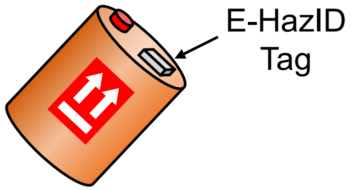


Developed E-HazID Tag Prototype

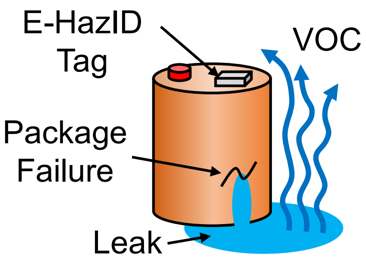
- Miniaturized wireless tag, easy to install
- E-label & HazCom, easy to input & output
- Four microsensors to detect all major issues
- Integrated robust optical liquid leak sensor
- Battery lasts for one year



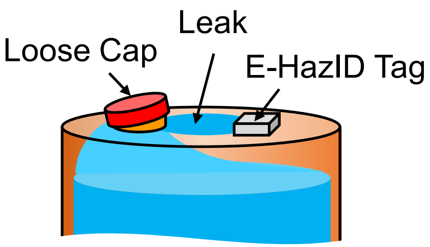
Gas Leak Detection



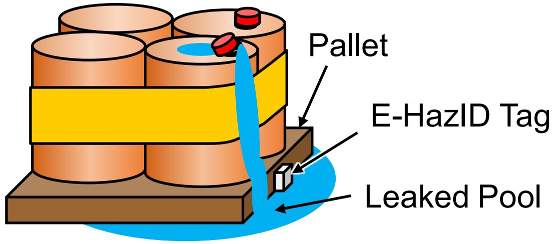
Overturning Detection



Liquid Leak Detection



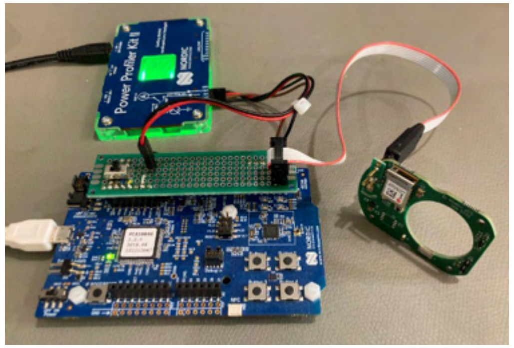
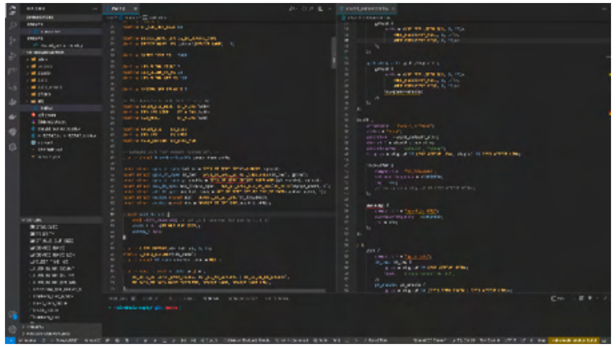
Liquid Leak Detection on Single Package



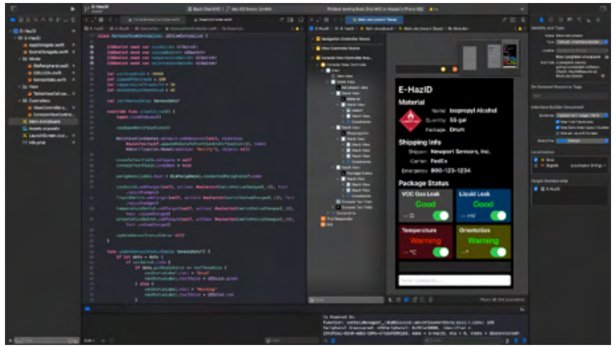
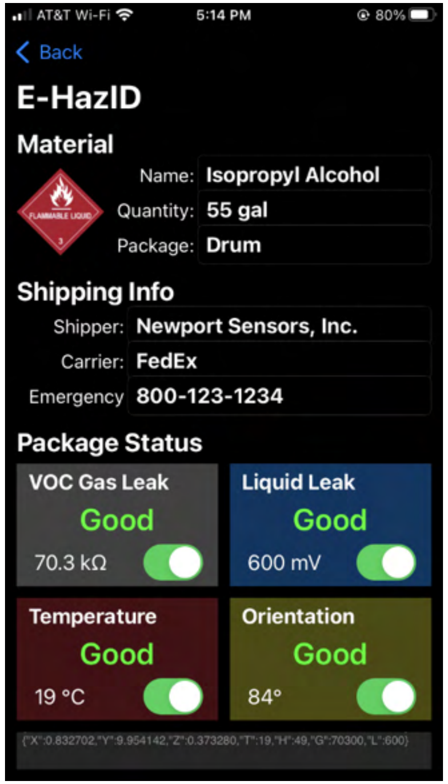
Liquid Leak Detection on Bulk Package

Phase I Accomplishments: E-HazID Software

- Firmware integrated into the tag circuit
- Mobile app serving as user interface
- Firmware integrated into the fixed radar circuit

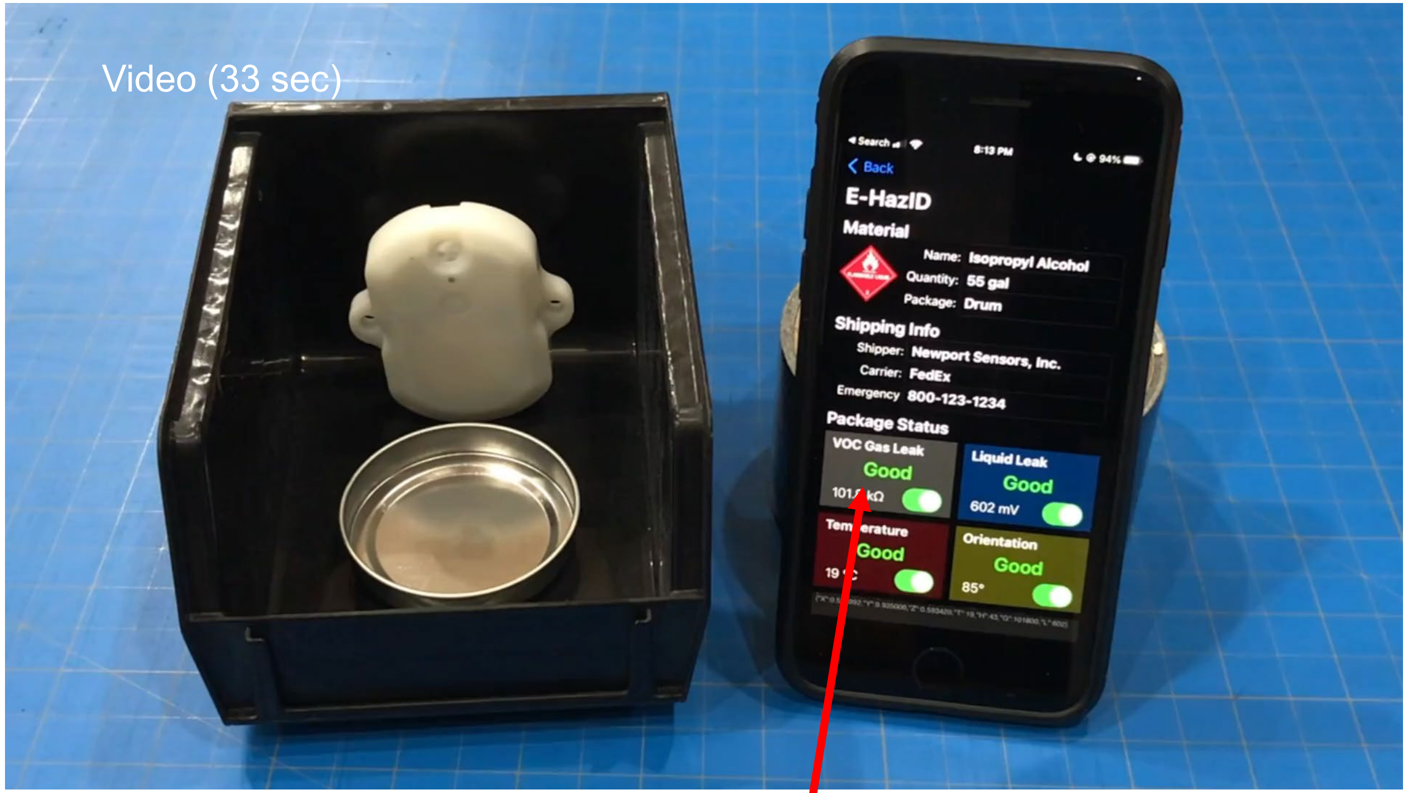
Firmware Development

Mobile App Development

Phase I Accomplishments: E-HazID Demonstration 1

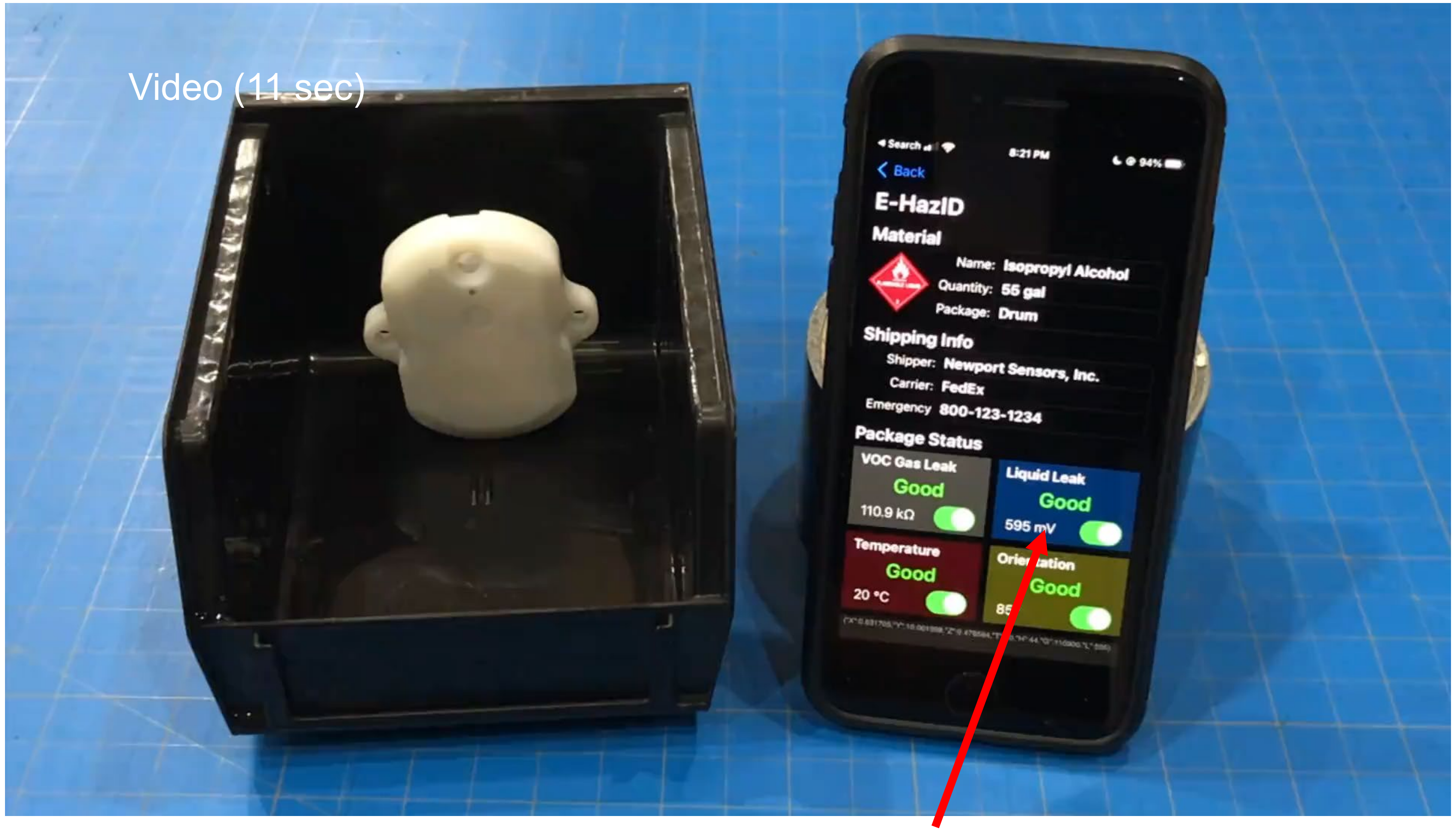
E-HazID tag successfully detected Isopropyl alcohol leakage within 30 seconds



See VOC Gas Leak Status

Phase I Accomplishments: E-HazID Demonstration 2

E-HazID tag instantly detected liquid leakage (water)



See Liquid Leak Status

Phase I Accomplishments: E-HazID Demonstration 3

E-HazID tag successfully detected a temperature rise of 2°C within 20 seconds

See Temperature Status

Phase I Accomplishments: E-HazID Demonstration 4

E-HazID tag immediately detected overturning

See Orientation Status

E-HazID Commercialization

Phase II Plan

- Develop an E-HazID system featuring dual wireless connectivity
- Conduct a month-long trial in collaboration with interested users
- Analyze collected data to train an AI algorithm for safety alerts based on sensor fusion

SBIR Phase I

Feasibility Demonstration

2023

→

SBIR Phase II

System Development & Field Validation

2024-2025

→

Post SBIR

E-HazID Product Launch

2027

E-HazID Features and Benefits

- Standalone system equipped with micro wireless tags for rapid deployment
- Tag integrates electronic HazCom with various sensors for continuous monitoring and real-time detection/alerts of all safety issues
- Dual wireless modes ensure robust communication even w/o Internet
- Features a user-friendly mobile interface
- AI-driven system for reliable safety alerts and valuable business insights

Gas Leak
- Flammable Gas

VOC Material Leak
- Flammable Liquid
- Flammable Solid

Non-VOC Leak
- Corrosive Material
- Oxidizer
- Organic Peroxide

Orientation
- Any Liquid

Shock
- Any

Temperature
- Misc. Hazardous

Detectable Safety Issues

Contact Information

Masato Mizuta, PI, Chief Engineer
Maria Feng, PhD, Research Advisor
Newport Sensors, Inc.

info@newportsensors.com
844-800-4248

Irvine, CA   www.newportsensors.com   New York, NY

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

23-PH4: Wearable PPE-Integrated Sensors for First Responders

November 28, 2023

Triton Systems – Chelmsford, MA

- Since 1992, Triton transitions R&D concepts to manufactured products
- Private equity investments + public non-dilutive funds
- Market-based focus areas:

✓ Personal Air Mobility
✓ Acoustics
✓ Sensing Systems
✓ **Human Systems**
✓ Ocean Systems
✓ Robotics
✓ Specialty Materials
✓ Structures
✓ Sustainment
✓ Artificial Intelligence

Triton Systems – Human Systems

- **Human-centered design** for delivering user-driven solutions
- Enhancing realism with prototypes and functional form models
- Methods include SME interviews and task-based prototype evaluations
- Through emphasis on the user, we improve design efficacy and increase user adoption

Sensor Products

Physiological Monitoring

Mixed Reality Training and Interfaces

Human & Occupational Performance

The Team

Cole Godzinski
Principal Investigator,
Mechanical Eng.

David Pierre, PhD
Product Lead,
Bioengineering & Sensors

James Saunders
Program Manager,
Director

Doug Freitag
Business Development,
Director

The Problem

- **HAZMAT incidents occur in chaotic, task-saturated environments.**
- Current technology:
  - Large, handheld, expensive, difficult to use with PPE, and can require difficult training and/or maintenance.

Image provided by consultant

The Need

- **PPE-integrated sensor**
  - Chemical detection for OSHA threshold limits
  - High sensitivity, durability, multi-chemical detection
- **Intuitive alerts**
  - Visually and auditorily saturated environment → Tactile display
  - Provide situational awareness and enhance communication

Image provided by consultant

The End Users

- First Responders
  - Training Level: Operations (firefighters)
    - » Defensive role: stay at a distance
  - Goal: **Understand the context of the hazard** to protect life, property, and the environment
- HazMat First Responders
  - Training Level: Technician/Specialist
    - » Offensive role: respond, contain, stop the release
  - Goal: **Identify** and **quantify** the chemical hazard present

HazMat PPE

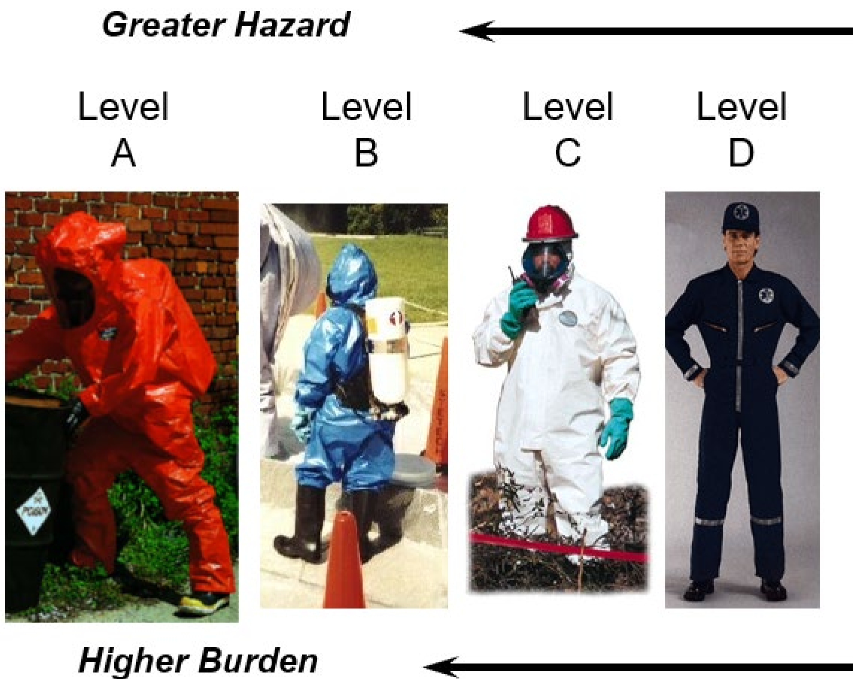


Image provided by consultant

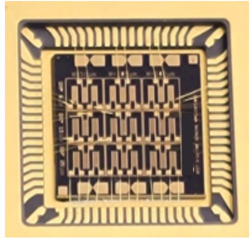
Wearable Alerting Tactile Cues for Hazard Response

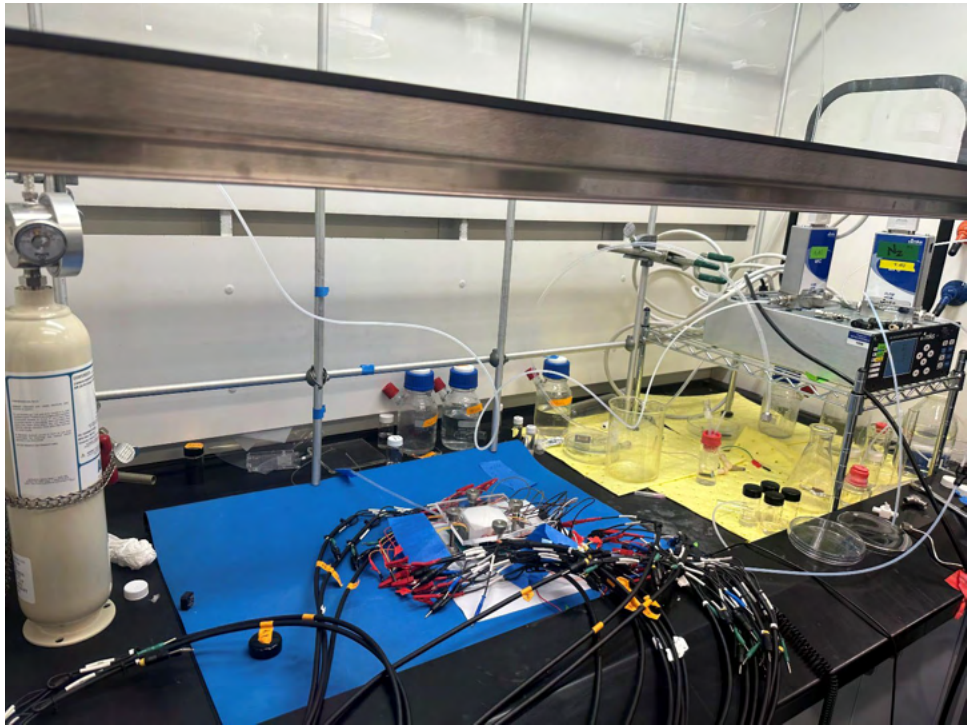
WATCHR's Components

- Sensor package with multi-chemical detection (outside)
- Washable tactile alerting display (inside)

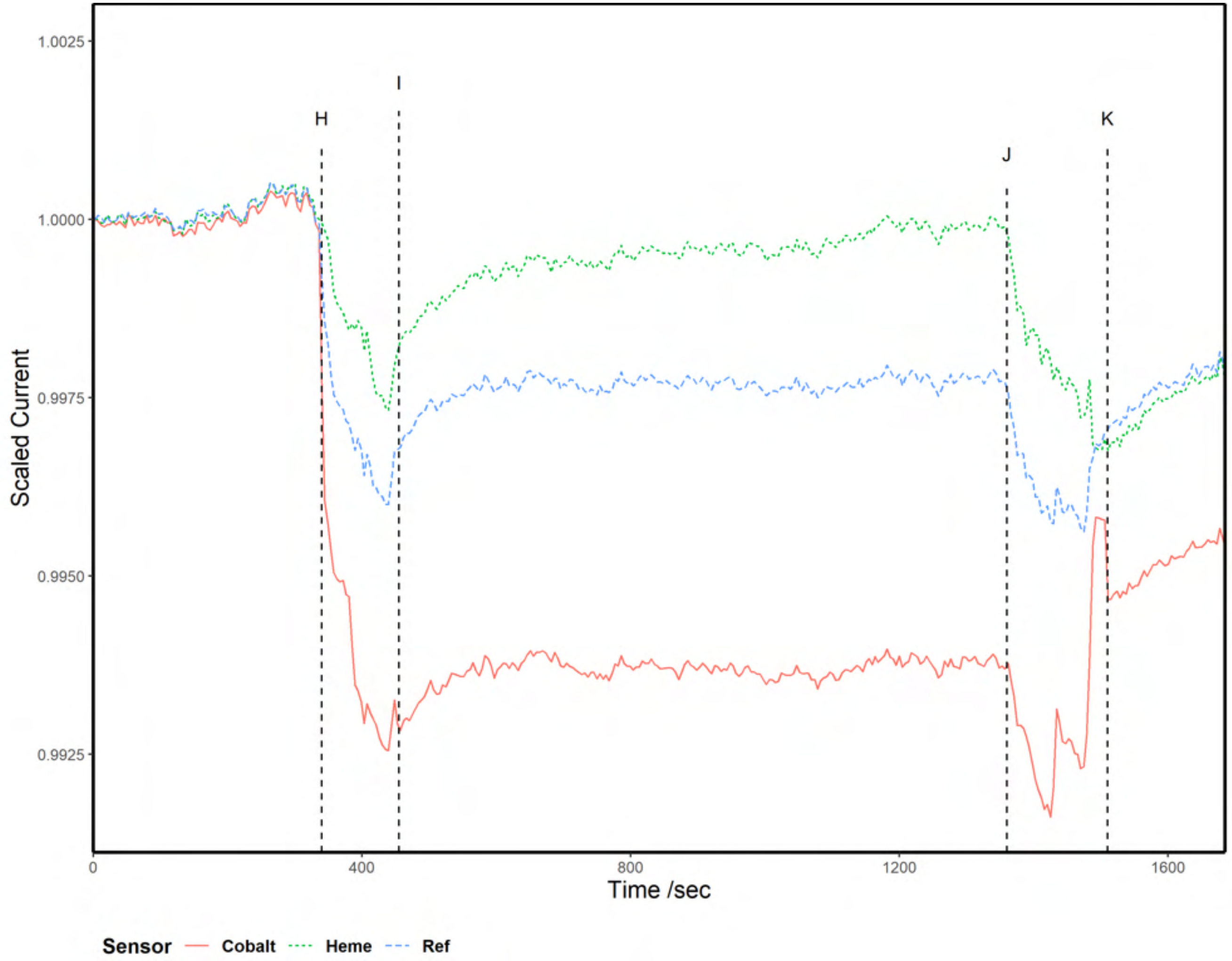
The Sensor

- Can be functionalized for multi-gas detection
- Up to 32 chips on a single sensor
- Detection redundancies reduce failure



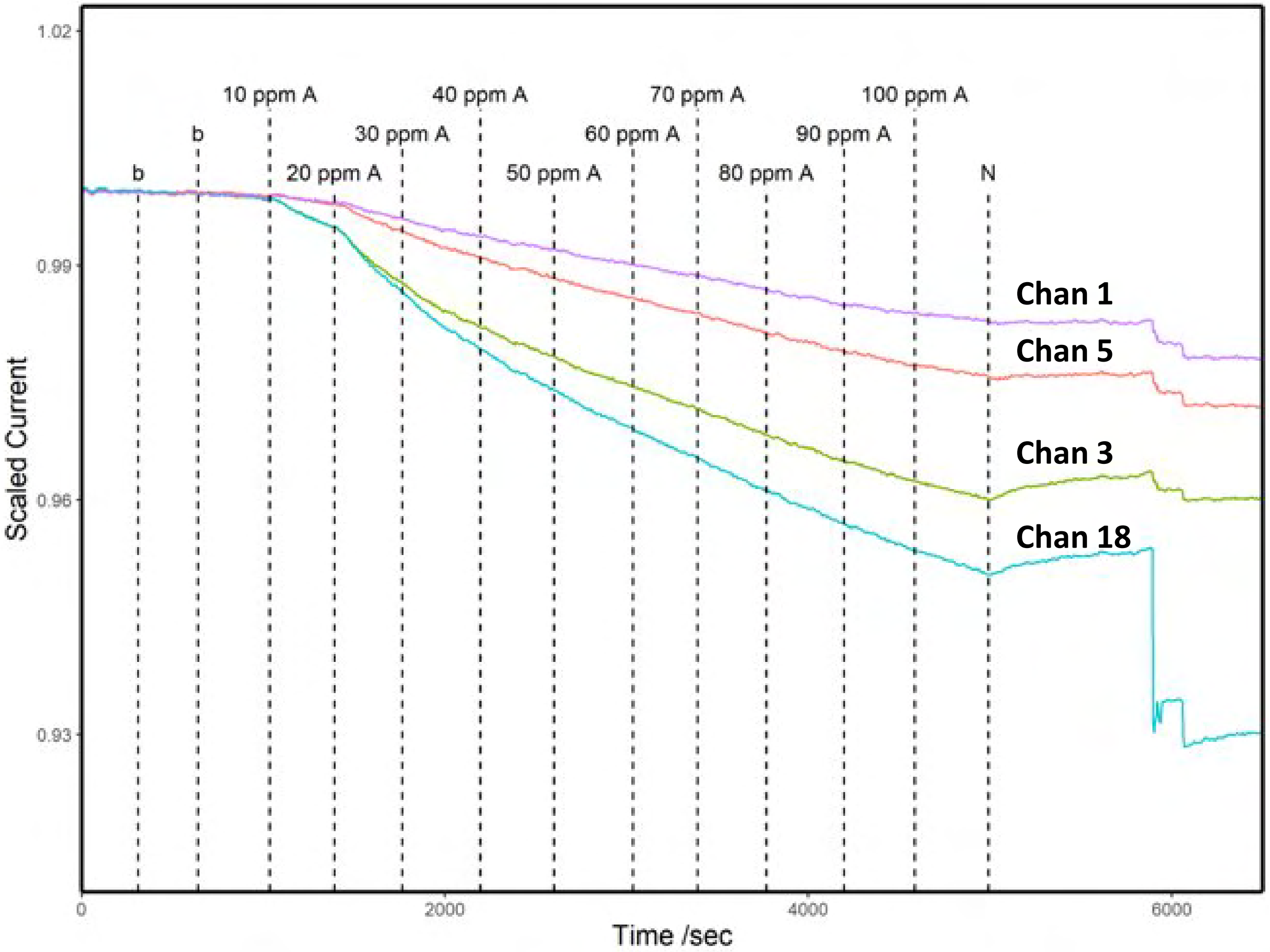


The Sensor – CO Detection



- Heme and Cobalt binding agents
- Baseline – Sensor exposed to open air
  - H – 300 ppm CO → immediate detection
  - I – 0 ppm CO → sensor recovery
  - J – 300 ppm CO → immediate detection
  - K – 0 ppm CO → sensor recovery

The Sensor – NH3 Detection



- Cobalt binding agents; 4 redundant Cobalt channels
- Baseline (b) – Sensor exposed to nitrogen
- Increased linear exposure to NH_3 from 10-100 ppm
- N – NH_3 reduced to 0 ppm
- No initial recovery

The Tactile Alerting Display

- Printed circuits are configurable for different form factors
- Can withstand 100 plus washes
- Reduces cognitive burden
- Eliminates distraction and cuts through environmental noise

The PPE Integration

- Sensor package integration includes:
  - Swappable sensor package
  - Integrated base stays on PPE
  - Pair to alerting display with NFC tag
  - Wireless communication between sensor, display, and response team

Contact Information

- Cole Godzinski, Principal Investigator
  cgodzinski@tritonsys.com

- Dr. David Pierre, PhD, Sensors
  dpierre@tritonsys.com

- James Saunders, Program Manager
  jsaunders@tritonsys.com

- Doug Freitag, Business Development
  dwfreitag@tritonsys.com

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

Encapsulated Microbes for Bioremediation of Hazardous Material Spills

November 28, 2023

Understanding the Problem and DOT Needs

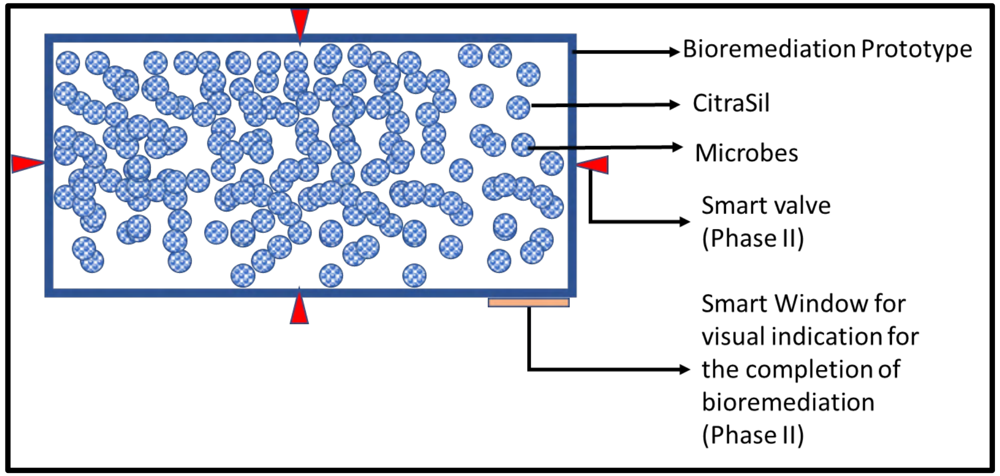
- 200,000 HAZMAT incidents
  - More than a million barrels of hazardous liquids were spilled
  - Two billion USD are spent
- Current cleanup methods are focused on immediate containment and physical removal
- Use of chemicals for remediation is neither environmentally friendly nor sustainable
- Short- or long-term bioremediation solution is therefore needed once the HAZMAT spill is contained or removed
  - Bioremediation: Use of microorganisms to break down environmental pollutants

Status Quo Solutions and Limitations

- Microorganisms are widely used for bioremediation
  - Not storage stable and requires protection from the external environment
  - Loss of performance when exposed to UV
- Microbes coated with synthetic or natural polymers
  - Does not absorb hydrocarbons and swells in water
- Silica and Granular Activated Carbon (GAC) are emerging new substrates
  - Excellent absorption capacity and environmentally safe. BUT
  - Not storage stable and requires protection from the external environment
  - Loss of performance when exposed to UV

Our Solution

- Encapsulated Microbes in Functionalized silica absorbent (CitraSil)
  - Inherent stability to the microbes against temperature, pH, and UV
  - Hierarchal particle morphology increases absorption capacity
  - Anionic surface charges for increased microbial stability
  - Handles land and waterfront spills
  - Low barrier to regulatory approval
  - Patent Pending Technology



Schematic illustration of the prototype (Phase I deliverable)

Phase I Results

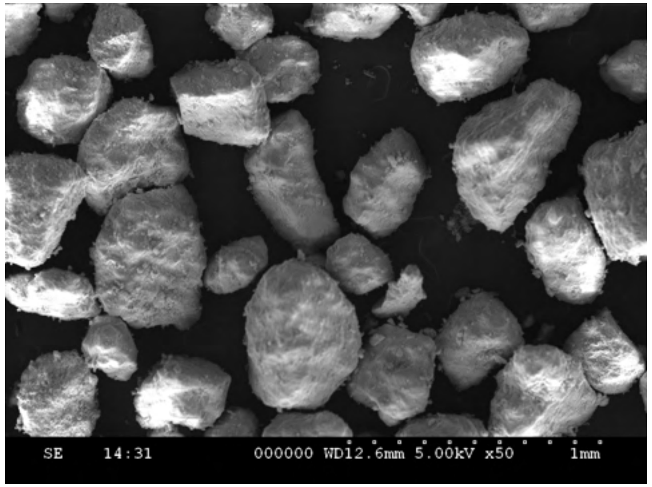
Technical Data and Product Features

Technical Data

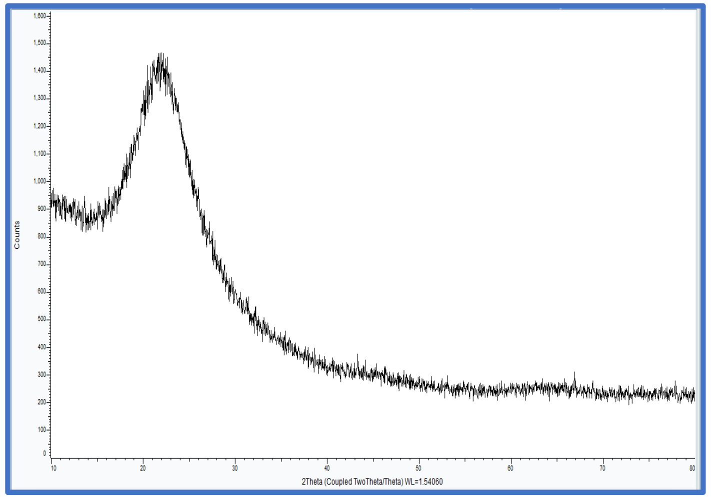
Property	Value
Volatile matter (%)	Max 1.4
Density (g/mL)	0.3±0.05
Angle of repose (deg)	18-24
pH (1% aqueous solution)	4-6
Particle Size (microns)	450±25
Total Porosity (%)	77-87
Total Pore Area (m^2/g)	156
HAZMAT Sorption Capacity (volume per 100 g of sample)	240
Zeta Potential (mv)	-26

- Identified and produced absorbents to meet customer's specific needs

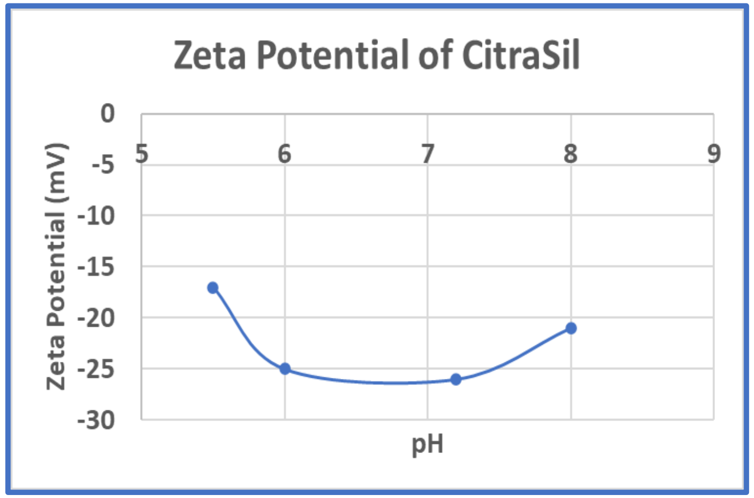
Product Features



SEM of CitraSil (10% citric acid modified)



XRD of CitraSil (10% citric acid modified)



Zeta Potential measurements of CitraSil at various pH

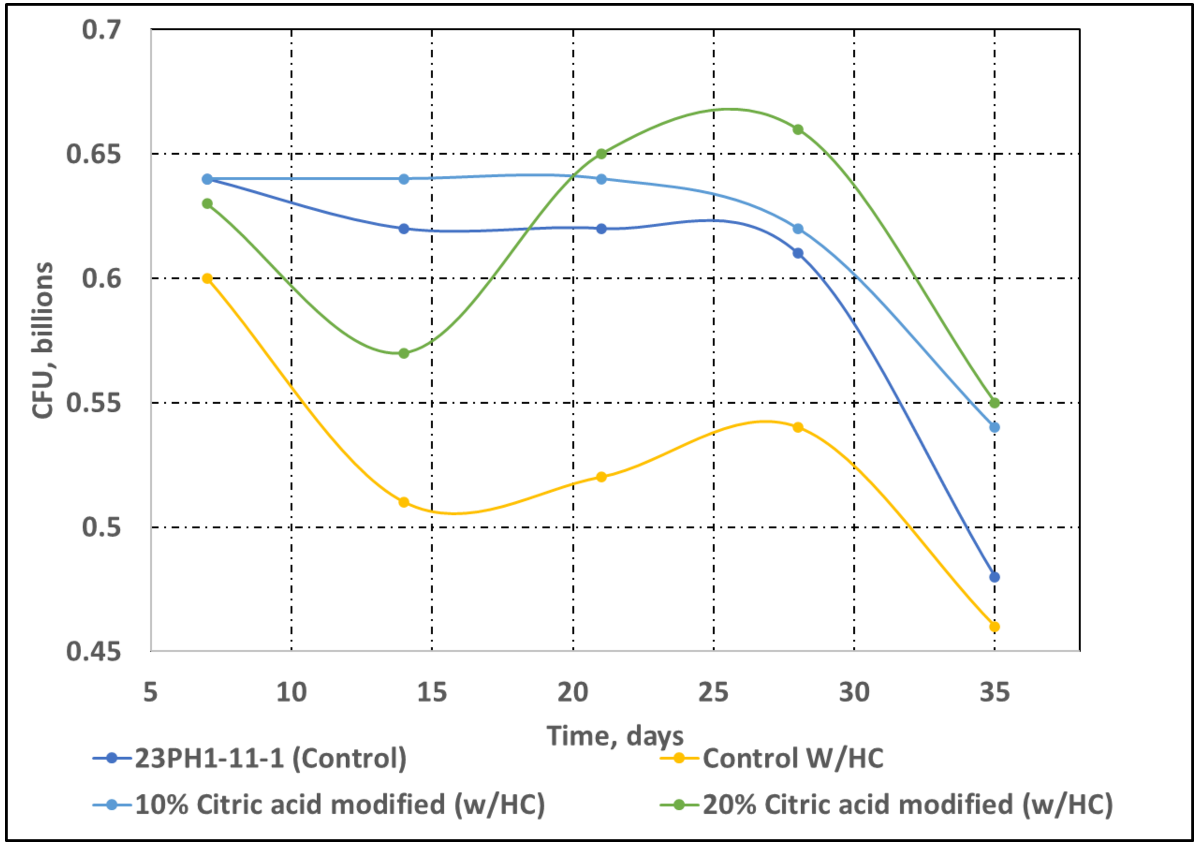
- High pore volumes for HAZMAT absorption
- Engineered anionic surfaces enable high microbial storage stability
- Can handle Hazmat spills in both land and waterways
- Safe to handle and Environmentally friendly

Phase I Results

Performance Evaluation

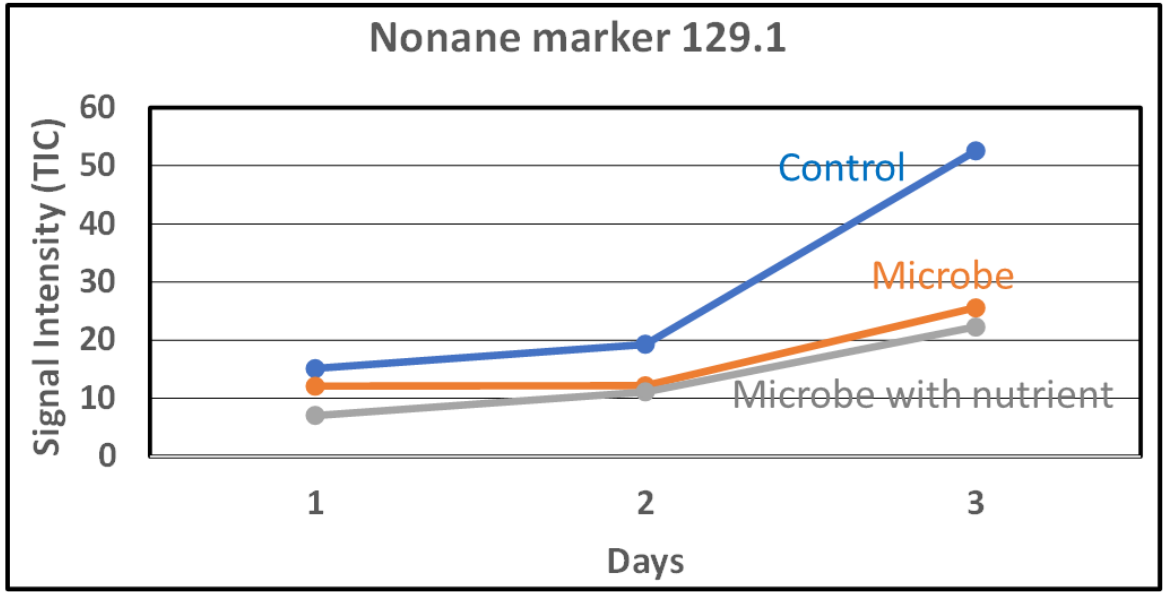
Microbial Stability

- Microbes are stable in the presence of a hydrocarbon mixture
- Absorption and remediation in one step
- Surface-modified absorbents meet the customer's stability requirements



Bioremediation

- Volatiles were analyzed using PTR-ToF
- Lower concentration of hydrocarbons in microbial product
- Significant Bioremediation within three days
- Product is highly effective in bioremediating hydrocarbons



Microbial Remediation of Nonane: PTR-ToF Results

Phase I Results

Techno-economic Assessment
TABA Support

Commercialization Readiness Assessment Report

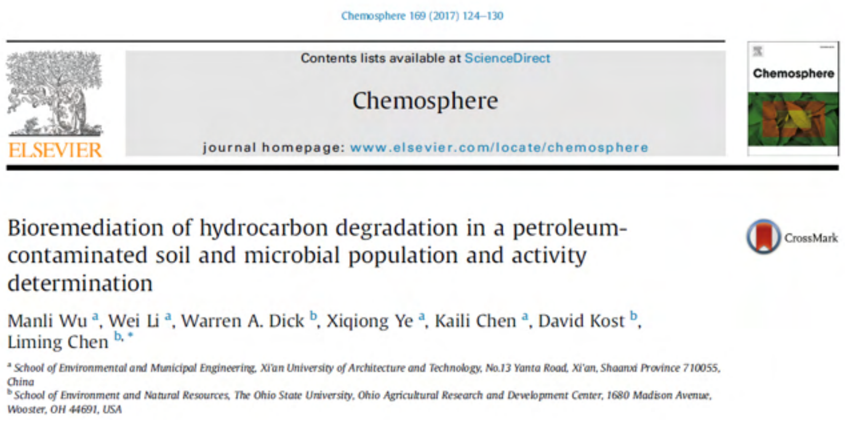
- TABA Recommendations
  - Differentiate from the top two competing products
  - Follow-up with potential partners
  - Immediate focus on off-shore marine spills and degrading xenobiotic compounds

- Techno-Economic Assessment
  - Revenue Projection (2029): $9.85 million based on 4.9 million units sold
  - Cost per pound is $3.9 to $5.8

TEAM

pd prioritydesigns

The Ohio State University



Chemosphere 169 (2017) 124–130

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

ELSEVIER

Bioremediation of hydrocarbon degradation in a petroleum-contaminated soil and microbial population and activity determination

Manli Wu [a], Wei Li [a], Warren A. Dick [b], Xiqiong Ye [a], Kaili Chen [a], David Kost [b], Liming Chen [b, *]

[a] School of Environmental and Municipal Engineering, Xi'an University of Architecture and Technology, No.13 Yanta Road, Xi'an, Shaanxi Province 710055, China

[b] School of Environment and Natural Resources, The Ohio State University, Ohio Agricultural Research and Development Center, 1680 Madison Avenue, Wooster, OH 44691, USA

BIO-CAT
Enzymes & Microbials

Human Centric Design and Prototyping

Hydrocarbon Degradation studies

Bacillus manufacturing and microbial stability testing

Contact Information

Ram Lalgudi

Aries Science & Technology LLC

Columbus, Ohio

lalgudir@ariesst.com

https://ariesst.com/

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

COMPACT BROADBAND LEAK DETECTOR FOR AUTONOMOUS VEHICLES

November 28, 2023

Adelphi Technology Inc.

- Adelphi History
  - Started from SBIR program
  - Now leading maker of neutron generators
  - 18 Employees, $4M annual revenue, majority engineers
  - Experienced with hardware product introduction

- New Opportunity with WKU
  - Gas analyzer technology started at Western Kentucky University
  - Broader market and attractive growth opportunity for Adelphi
  - Can combine novel technology with commercial experience
  - Spinning out new company

Conventional Gas Monitoring

- Conventional laboratory gas chromatographs (GCs) are not suitable for monitoring in the field.
- Conventional leak detectors: cross sensitive and cannot identify complex chemicals. Typically designed for simple gases.
- Adelphi compact GC advantage: monitoring of gases and volatile organic compounds (VOCs) in the field.

Adelphi Compact GC

- Broad dynamic range: broad range of detectable gases and broad range of concentrations
- Does not use PID/FID detector, utilizes solid state detector instead

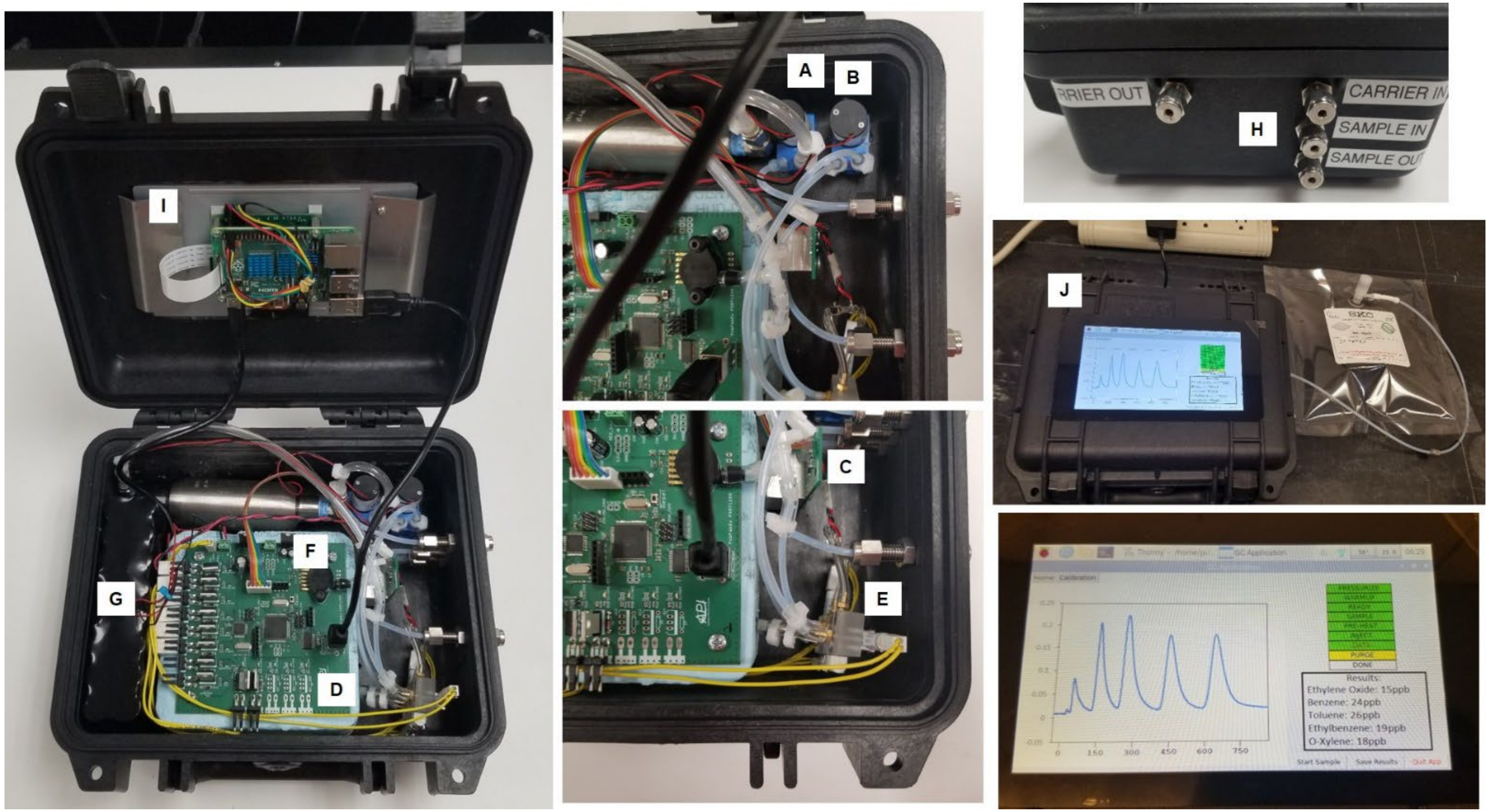
- Modular design with interchangeable columns, detectors and software
- Completely portable for field use. Battery powered, no laptop attached

Adelphi Compact GC (continued)

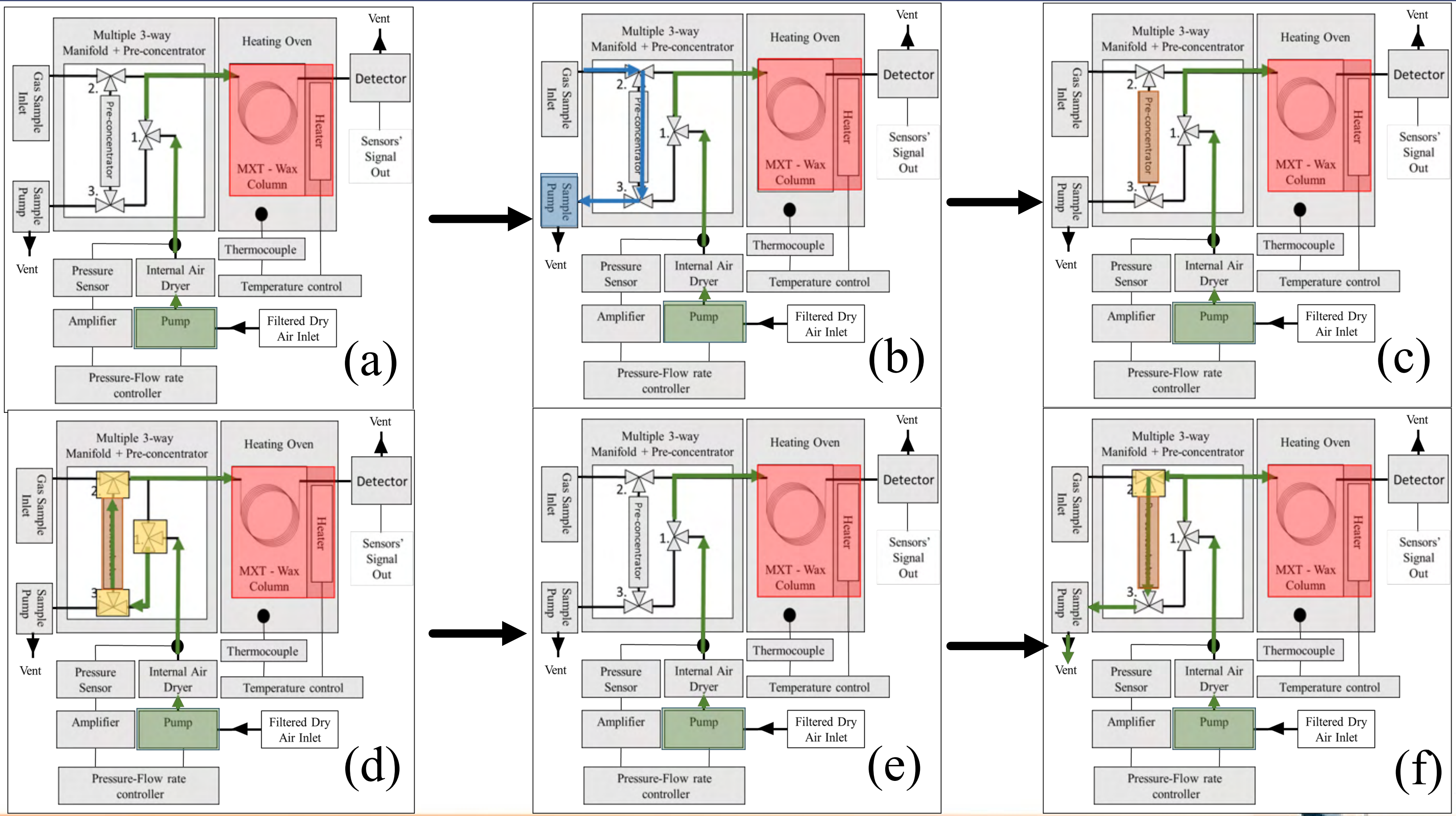
- Automated detection and concentration measurements, operator is not involved
- Automated sample collection with the internal pump, no syringe injection needed
- Low cost. Many devices can be purchased for monitoring multiple points
- Multisensory chromatography with novel solid-state detector

Adelphi Compact GC Architecture

A Carrier Gas Generation Pump
B Sample Pump
C Detector Module
D GC Column Oven Assembly
E Injector Module with Pre-concentrator and Cooling Fan
F Microprocessor Control Board
G Internal Battery
H Sample inlet
I Raspberry Pi 4 computer
J 7” 720P LED touchscreen

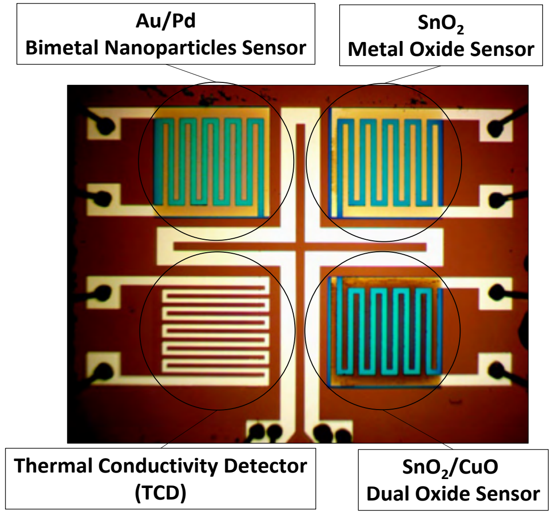


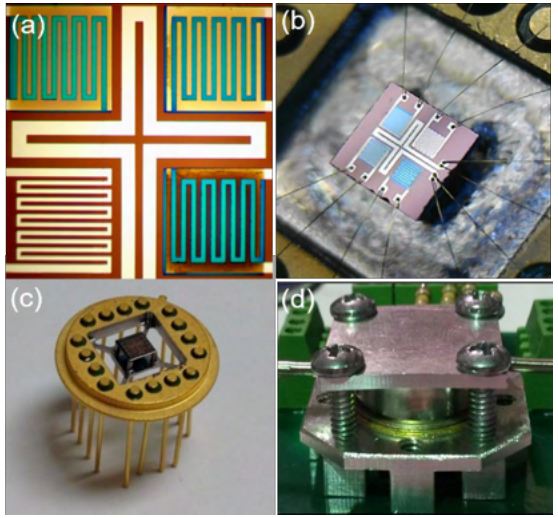
Adelphi GC Operating Cycle



Adelphi Novel Solid State GC Detector

- PPB level of detection
- Ultra-fast response and Recovery (ms)
- No long-term drift
- Great reproducibility (3% performance variations over all the products ever manufactured)



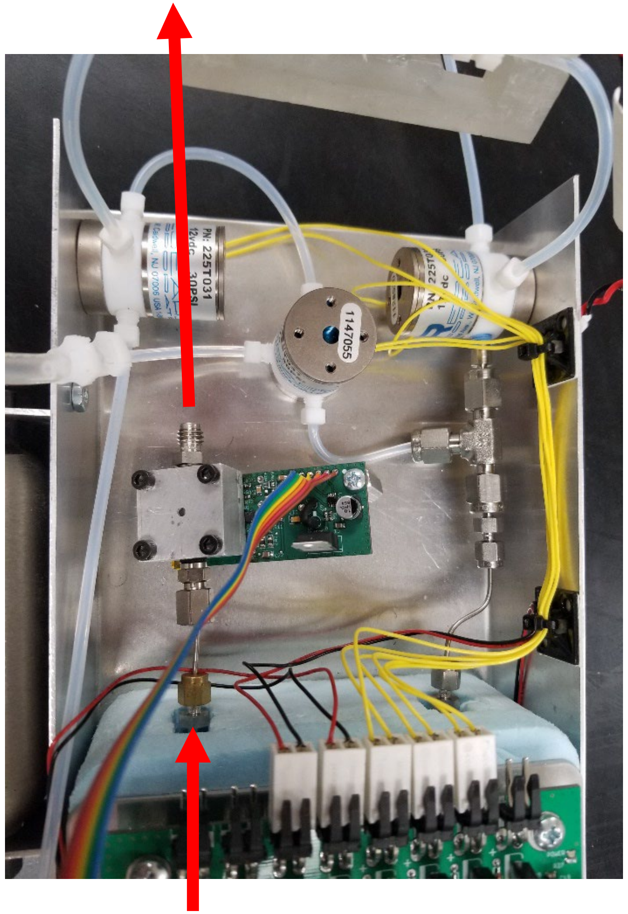


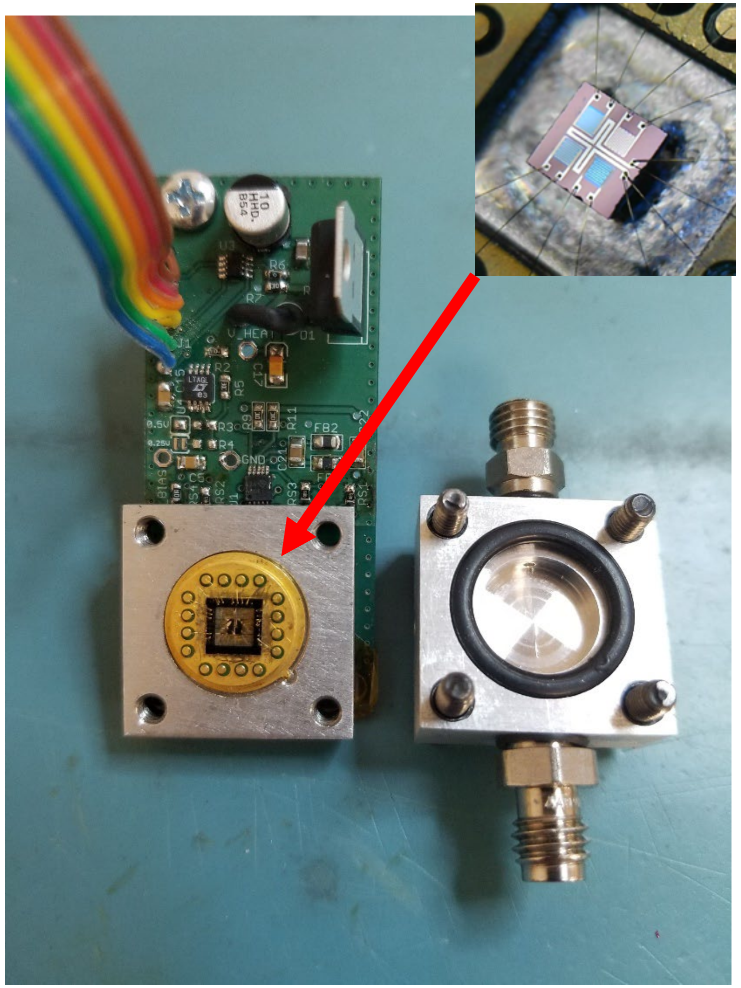
Dobrokhotov, V.; Larin, A. Doped, Metal Oxide-Based Chemical Sensors. U.S. Patent 10,132,769, Nov. 20, 2018.

Alexander Larin, Phillip C. Womble and Vladimir Dobrokhotov, Novel highly-integrated MEMS based solid state detectors for analytical gas chromatography, Sensors and Actuators B (Chemical), Sensors and Actuators B 256 1057–1068 (2018). https://doi.org/10.1016/j.snb.2017.10.046

Vladimir Dobrokhotov and Alexander Larin, Multisensory Gas Chromatography for Field Analysis of Complex Gaseous Mixtures, ChemEngineering 3(1) 13-30 (2019). https://doi.org/10.3390/chemengineering3010013

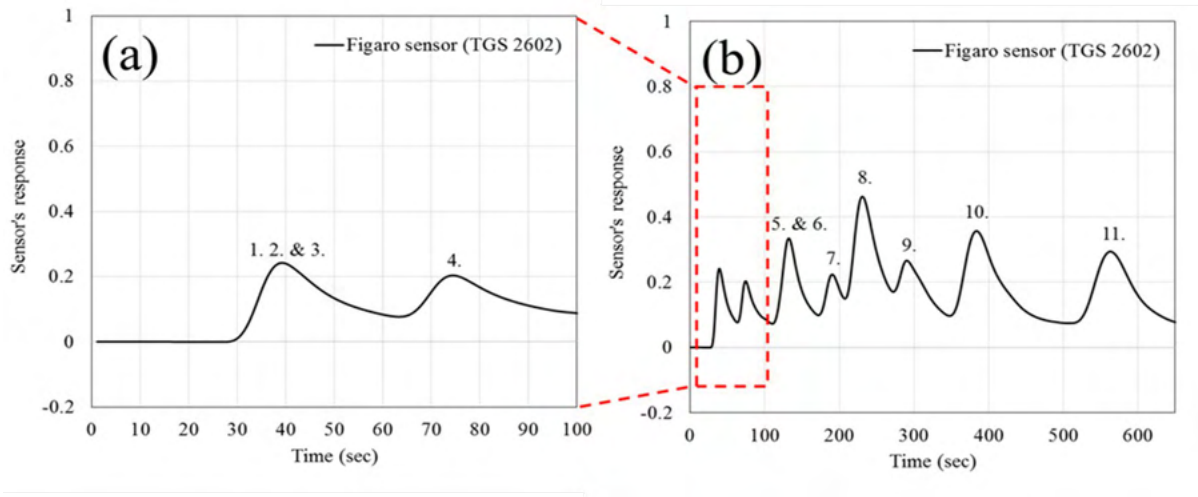
Integrated Detector Inside of a Flow-Cell





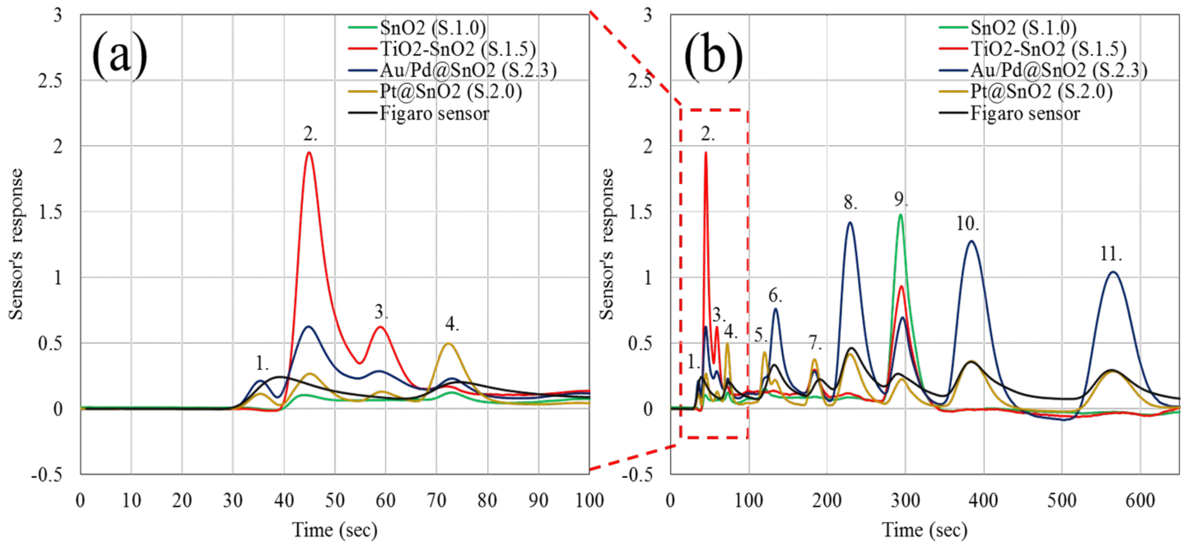
CONVENTIONAL DETECTOR

Gas chromatogram of Mix. 3 by using conventional non selective MOX detector (a) zoomed image of light compounds and (b) the full gas chromatogram. (1. Carbon Monoxide 10 ppm, 2. Hydrogen sulfide 100 ppb, 3. Ethyl-Mercaptan 50 ppb, 4. Acetone 50 ppb, 5. Ethanol 50 ppb, 6. Benzene 10 ppb, 7. Unknown, 8. Toluene 10 ppb, 9. Water, 10. Ethylbenzene 10 ppb, 11. O-Xylene 10 ppb).



NOVEL DETECTOR

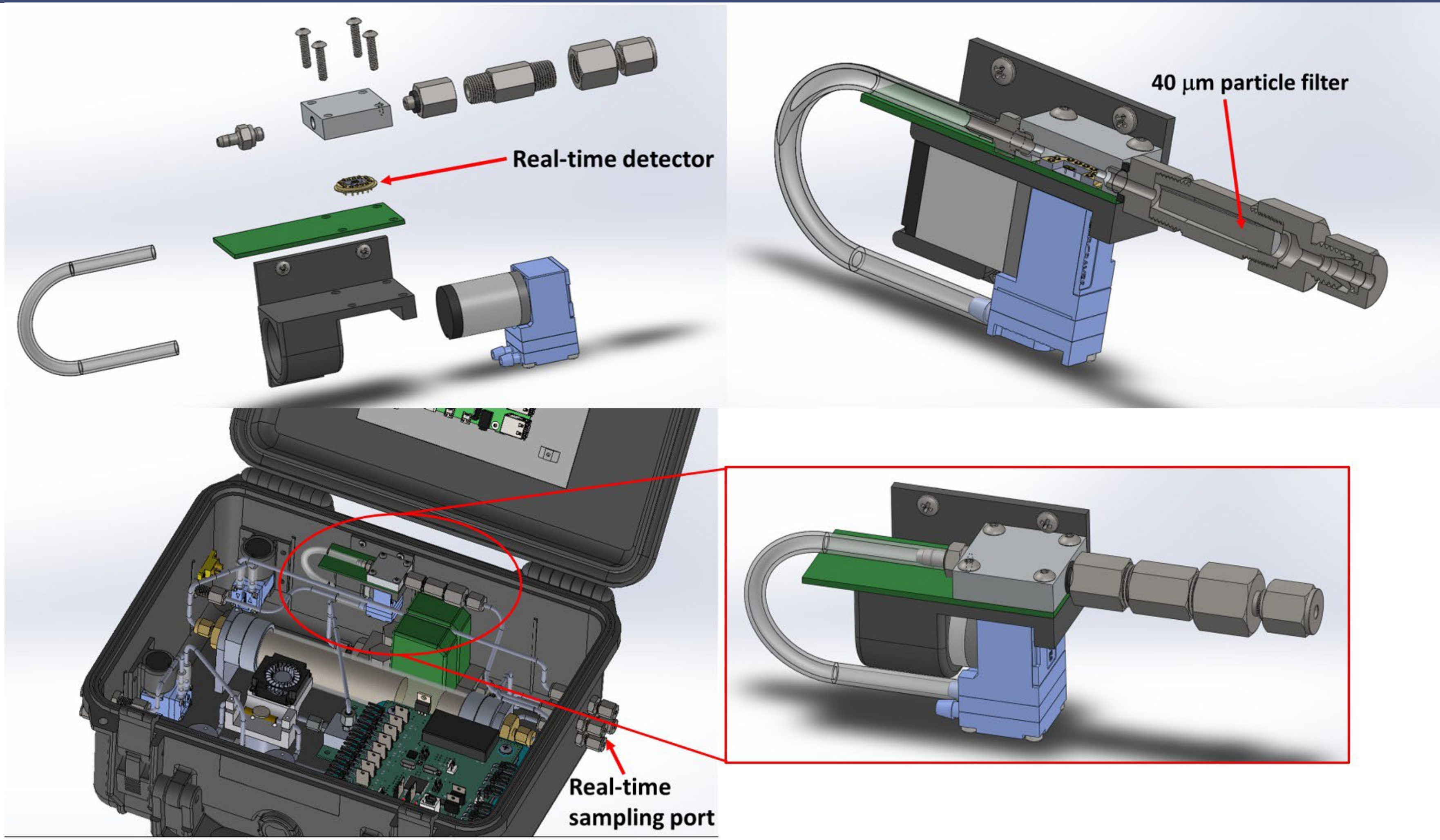
Gas chromatogram of Mix. 3: (a) zoomed image of light compounds and (b) the full gas chromatogram. (1. Carbon Monoxide 10 ppm, 2. Hydrogen sulfide 100 ppb, 3. Ethyl-Mercaptan 50 ppb, 4. Acetone 50 ppb, 5. Ethanol 50 ppb, 6. Benzene 10 ppb, 7. Unknown, 8. Toluene 10 ppb, 9. Water, 10. Ethylbenzene 10 ppb, 11. O-Xylene 10 ppb).



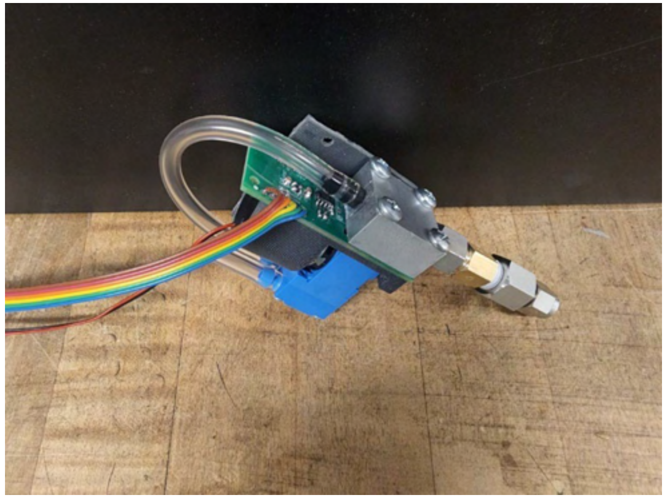
Integrating Real-Time Monitor with GC

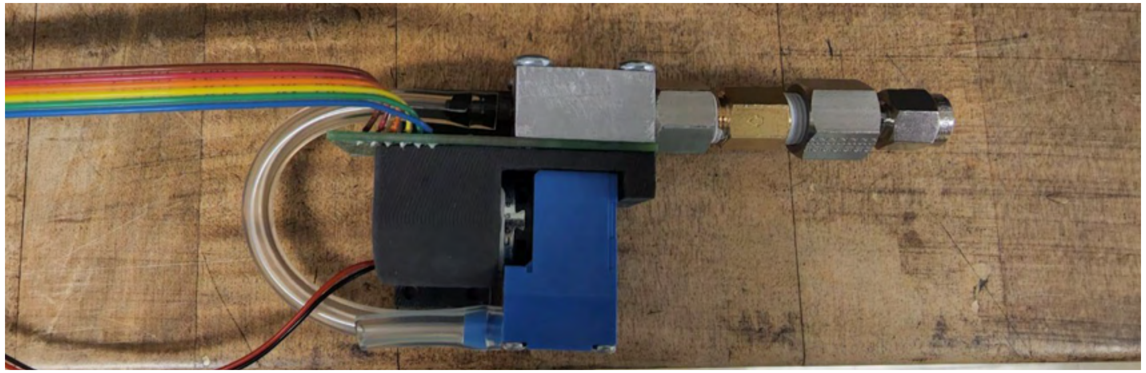
- Efficient monitoring of hazardous leaks can only be achieved by using an integrated approach combining real-time sensors and compact gas chromatograph.
- Real-time sensor systems are ideal for sudden spikes in concentration.
- Real-time sensors are not as useful for long term trending as gas chromatography.
- Adelphi leak detection system utilizes both techniques. This approach adds another level of data verification and significantly enhances system redundancy.

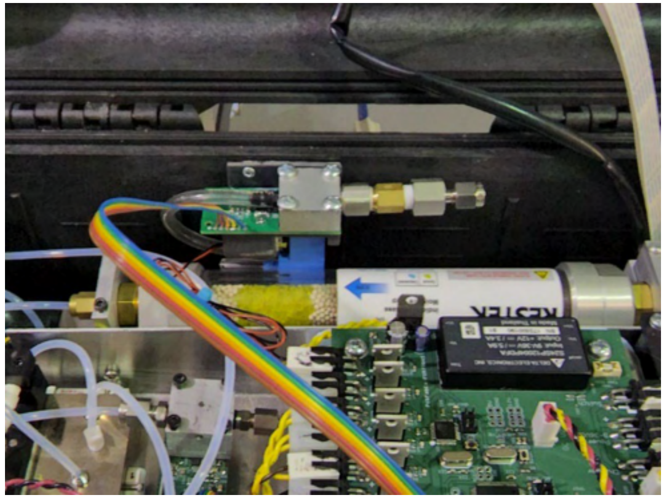
Integrating Real-Time Monitor with GC

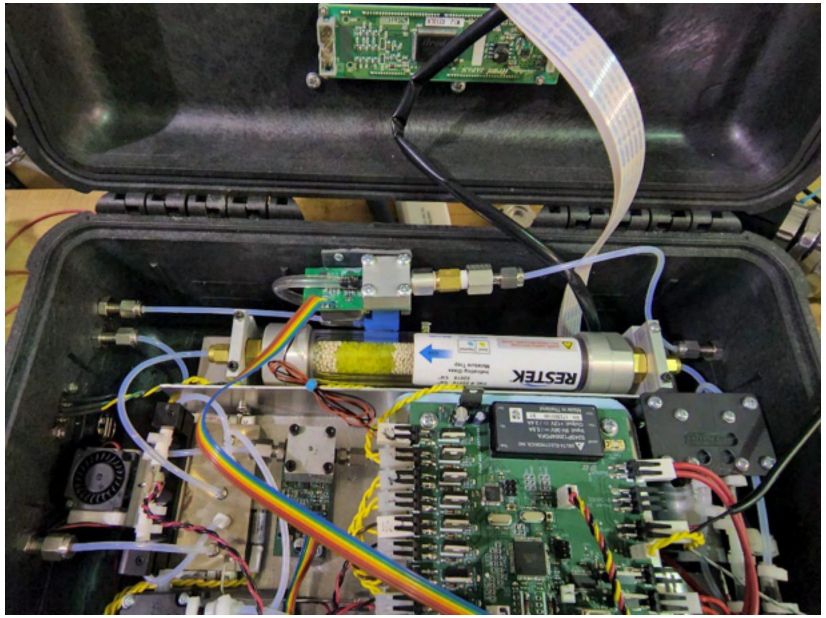


Integrating Real-Time Monitor with GC

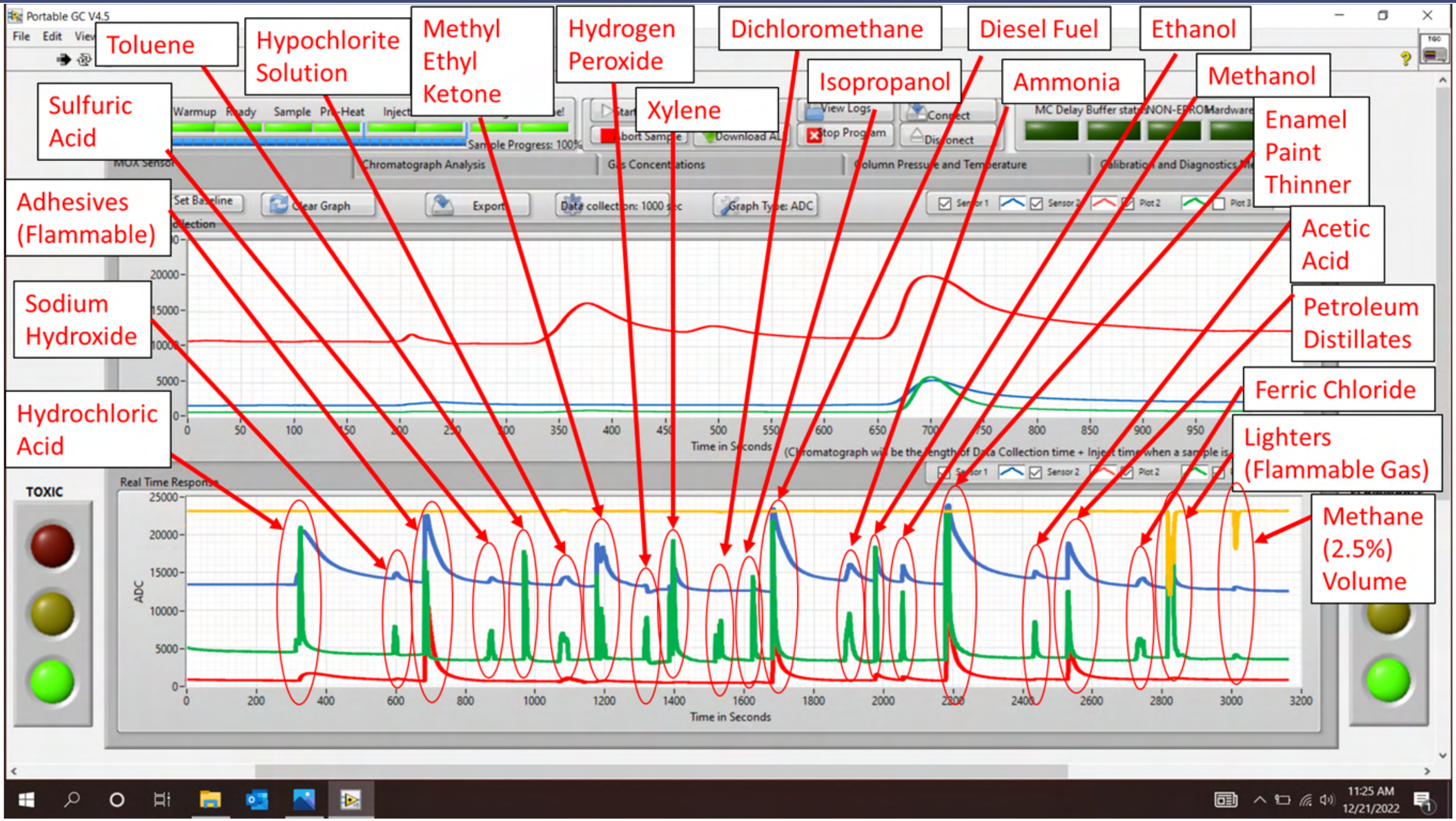






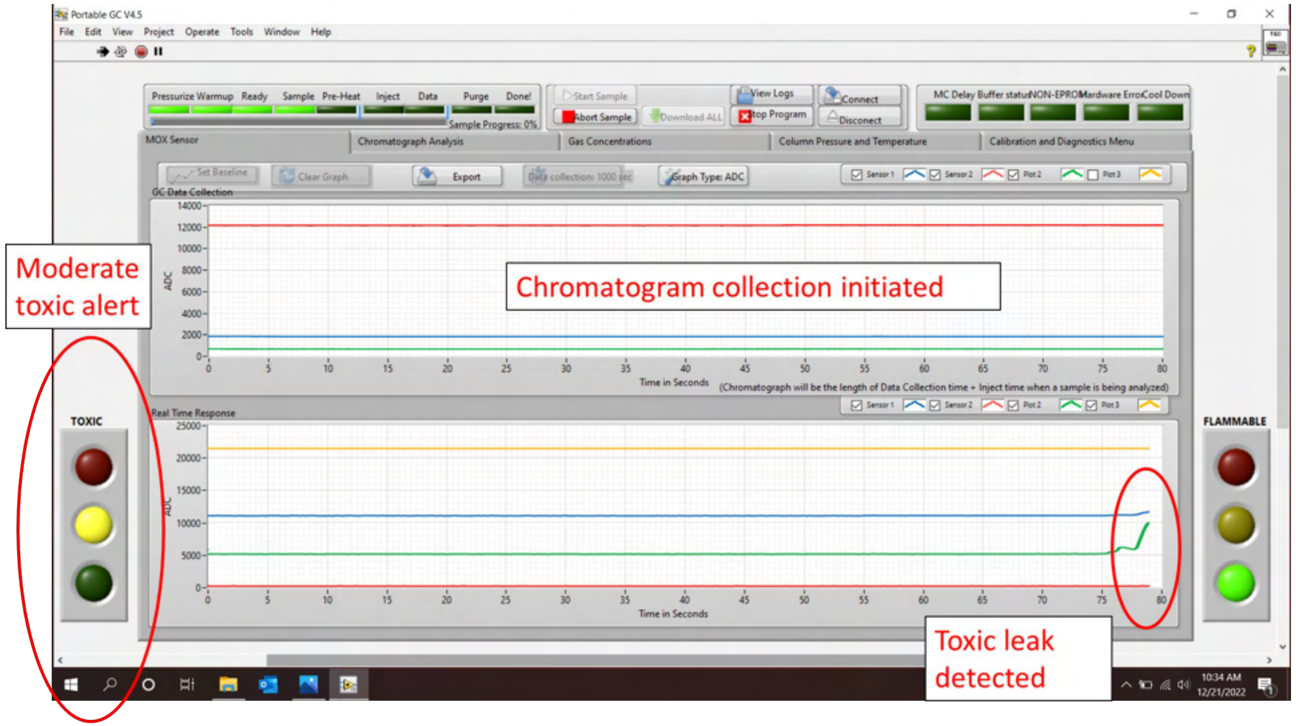


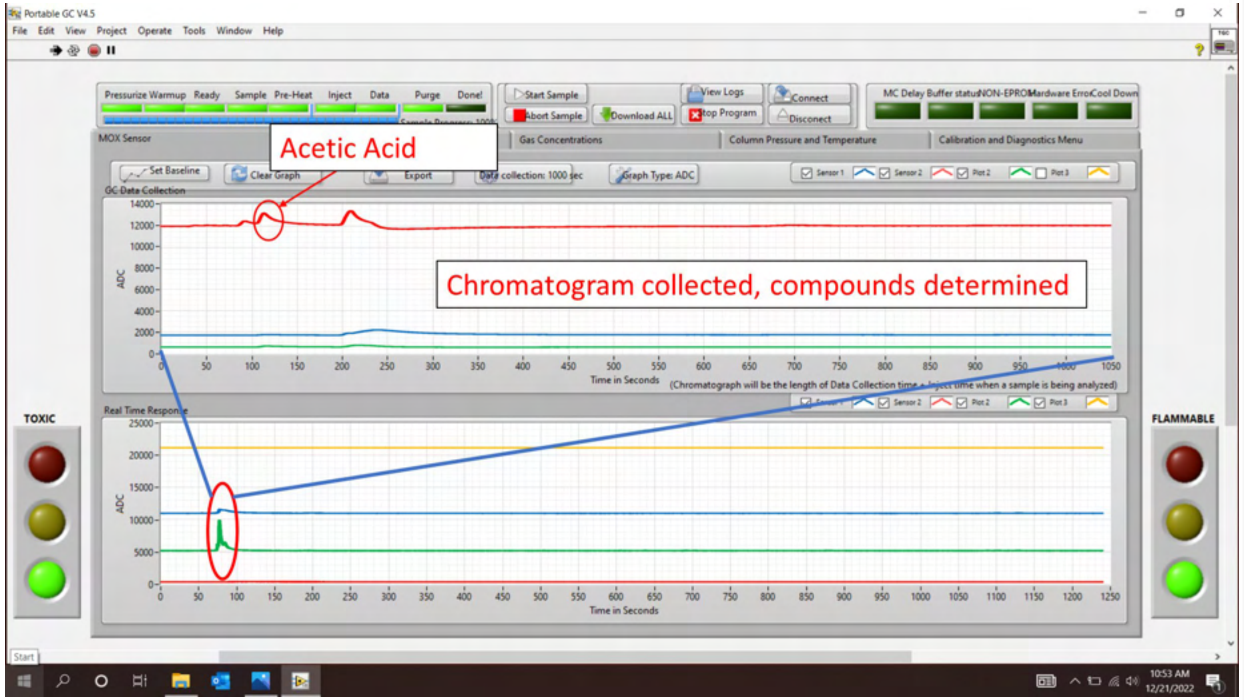
Real-Time Monitor Output



Integrating Real-Time Monitor with GC

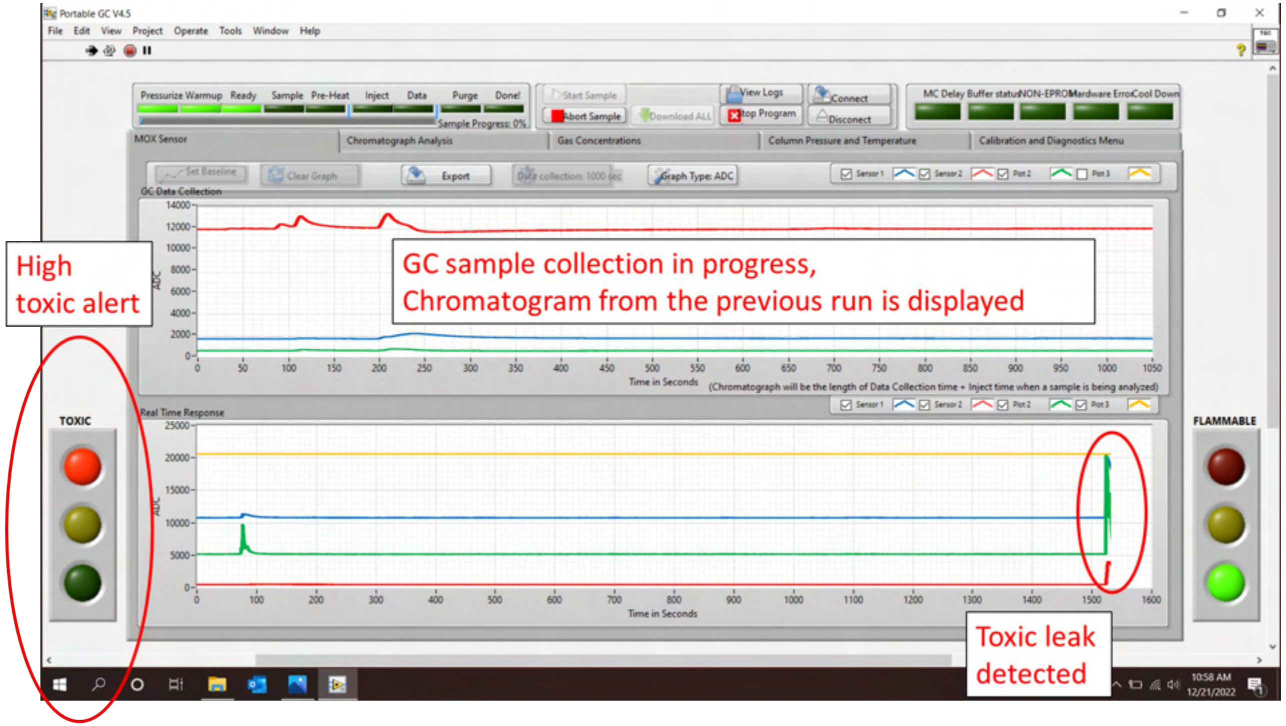
Acetic Acid (3% Household Vinegar)

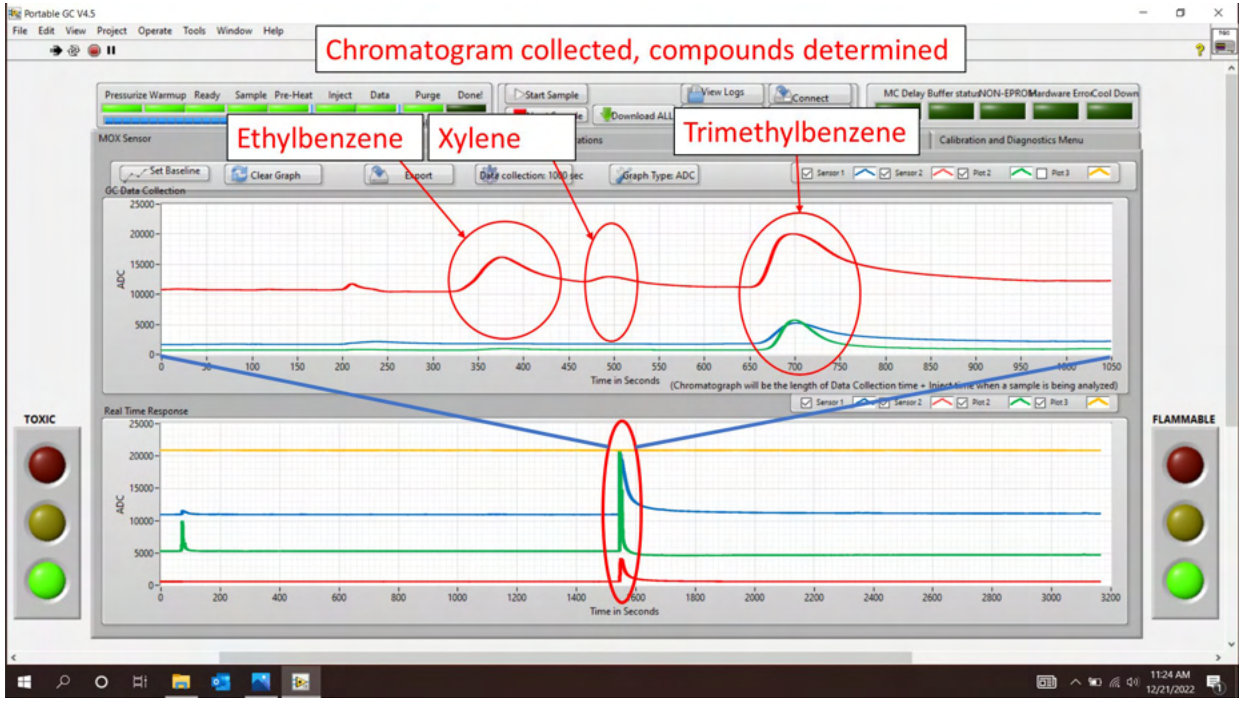




Integrating Real-Time Monitor with GC

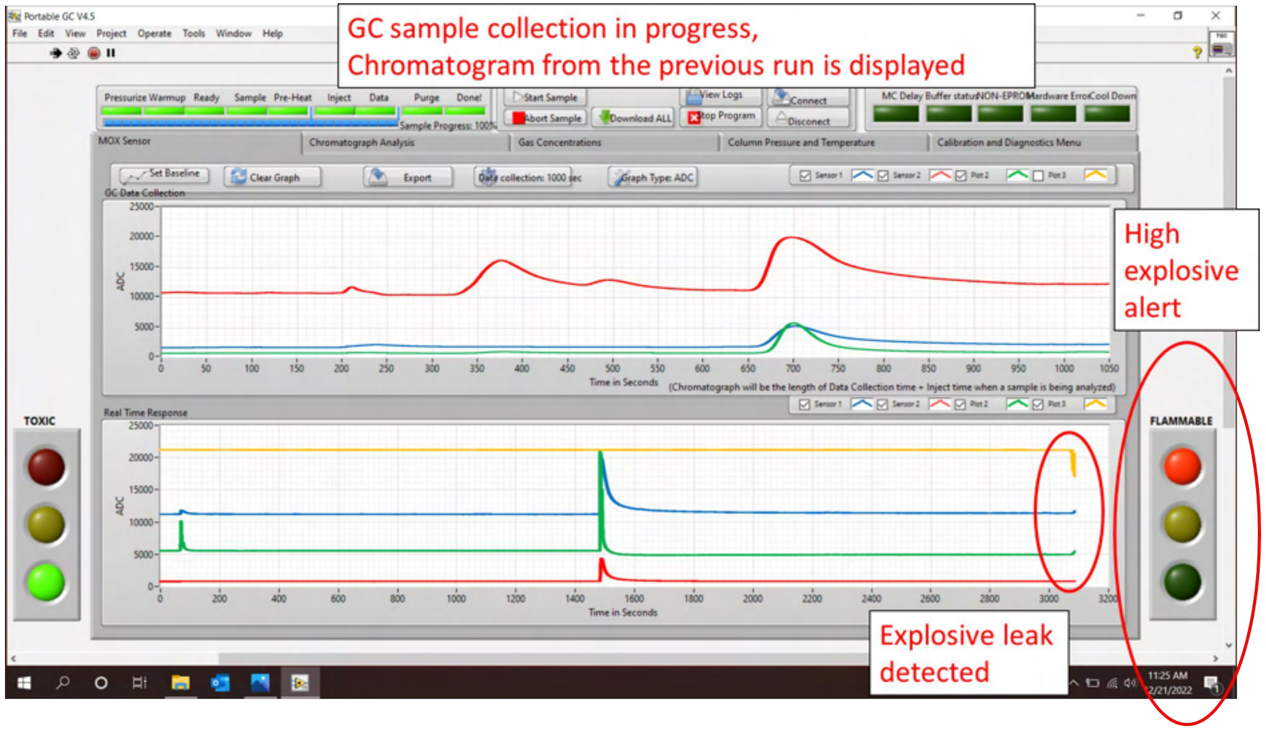
Enamel Paint Thinner

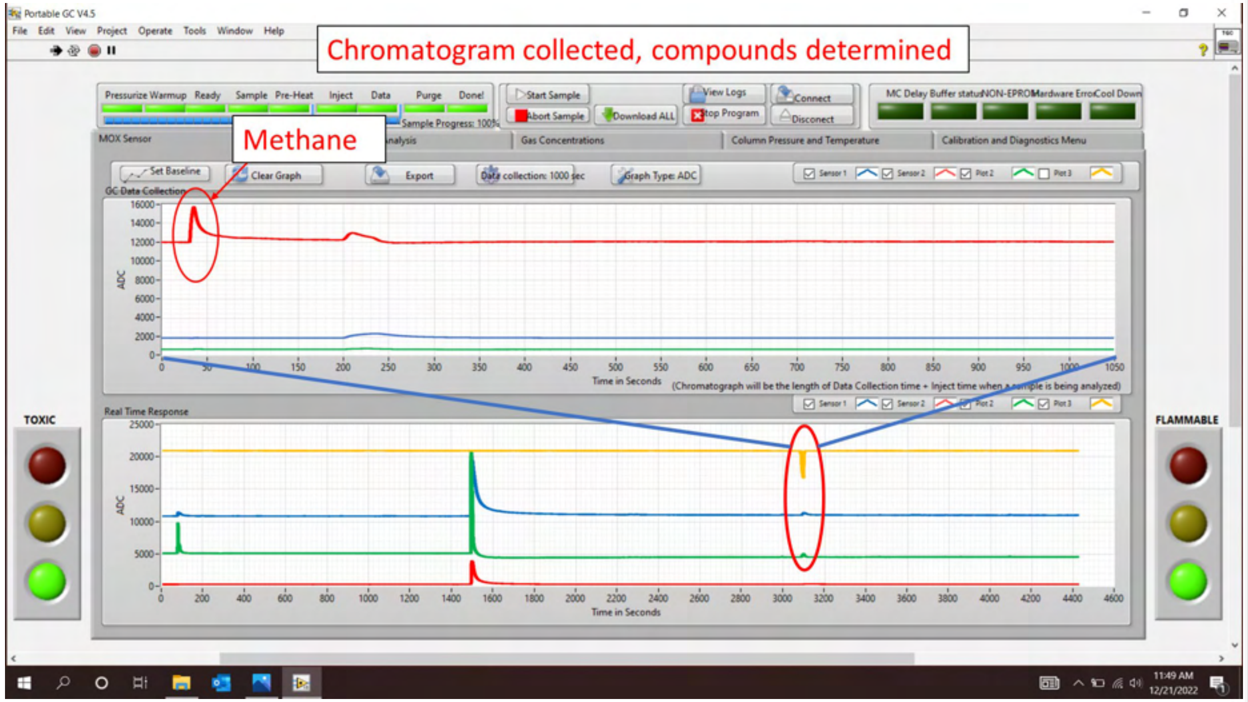




Integrating Real-Time Monitor with GC

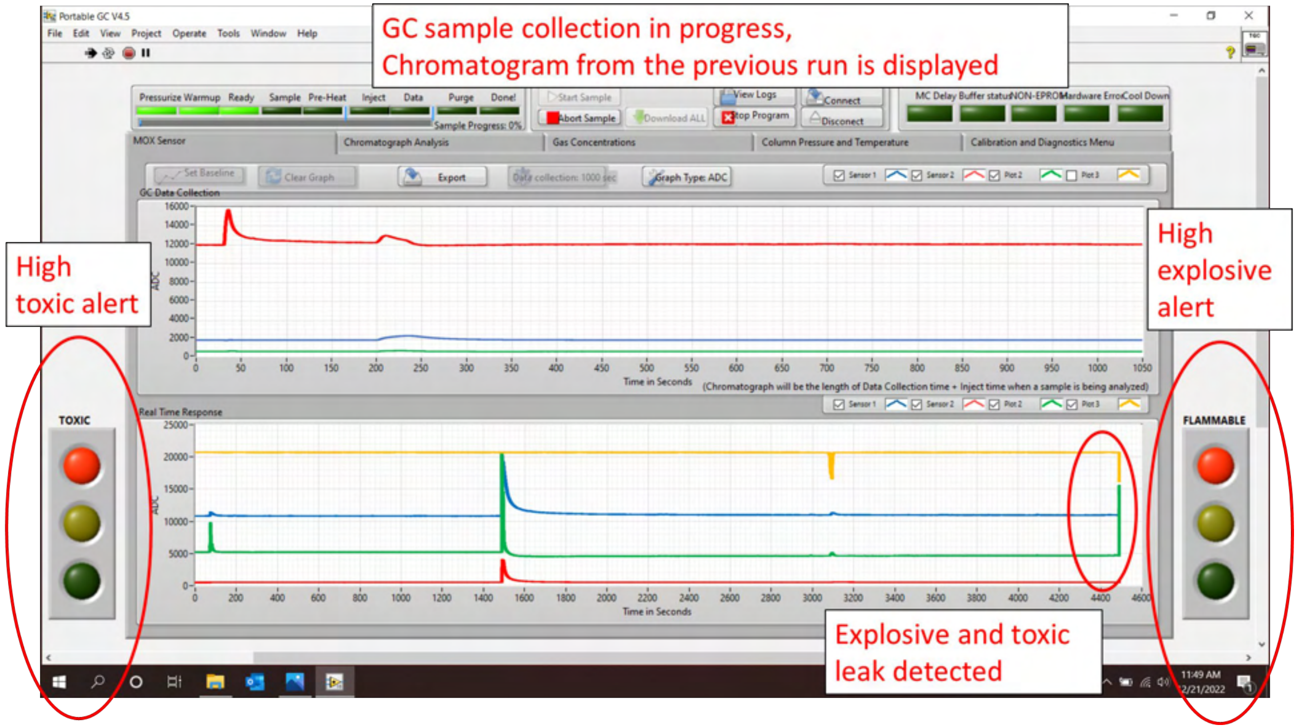
1% Methane in Synthetic Air

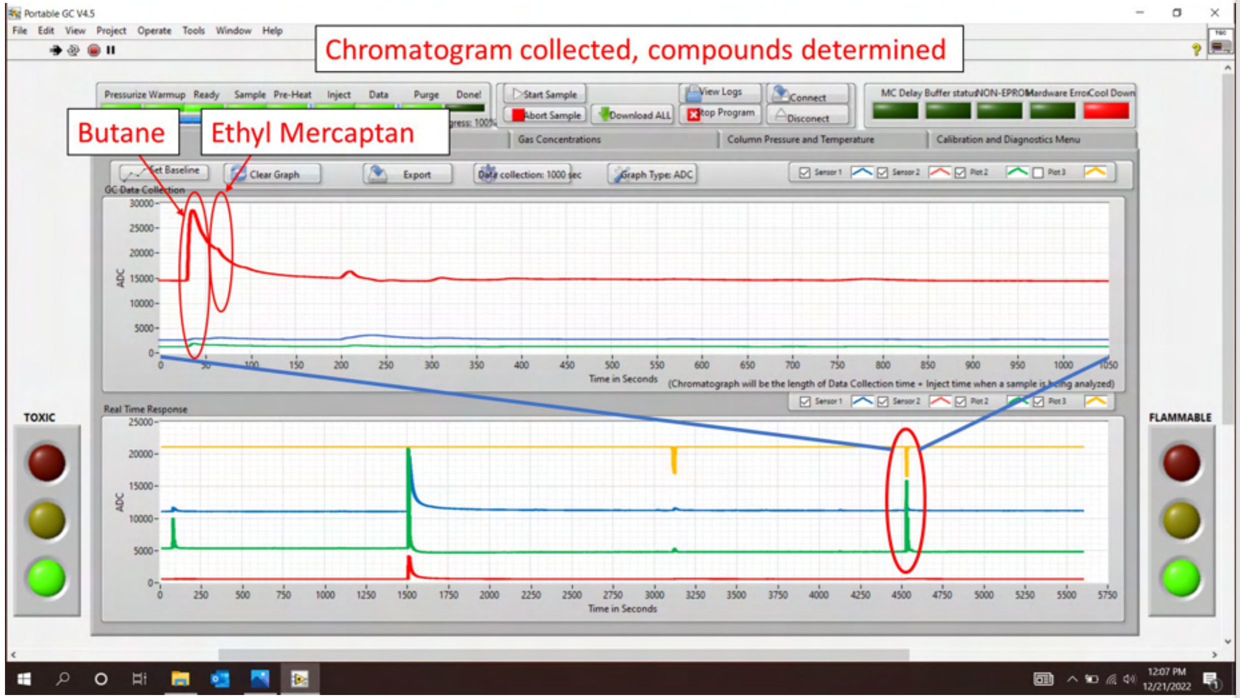




Integrating Real-Time Monitor with GC

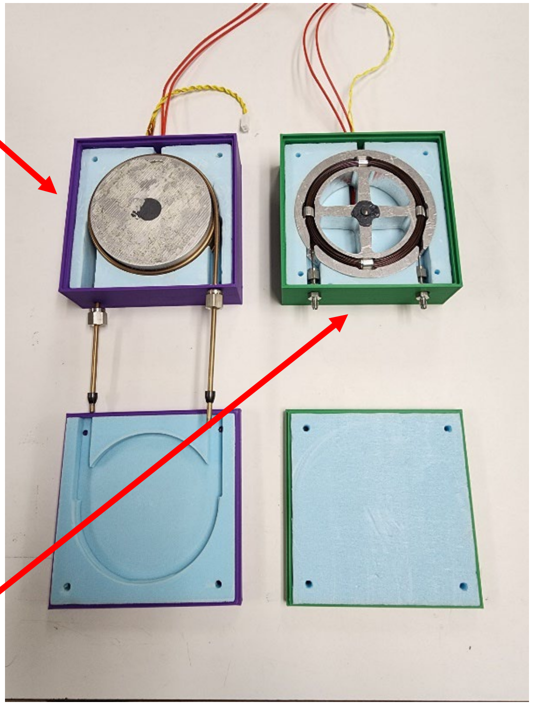
Butane and Ethyl Mercaptan Mix





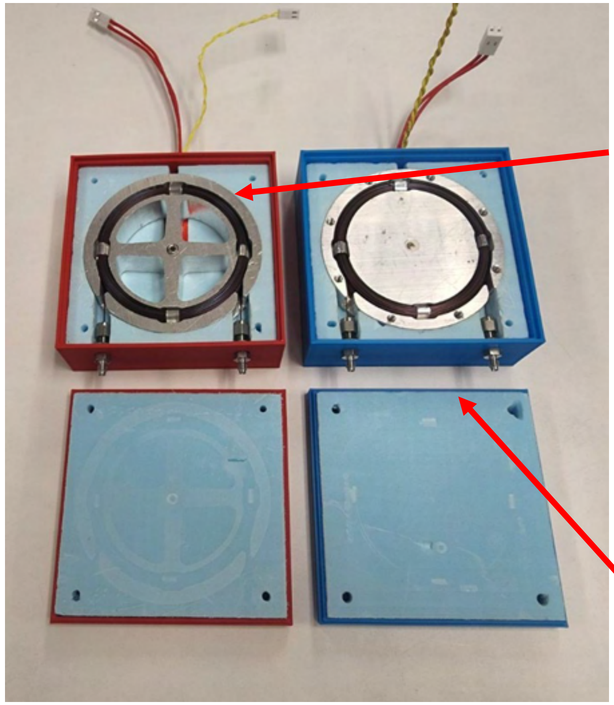
Modular Design: Column Specificity

CarboWax packed column. Targeting light compounds.



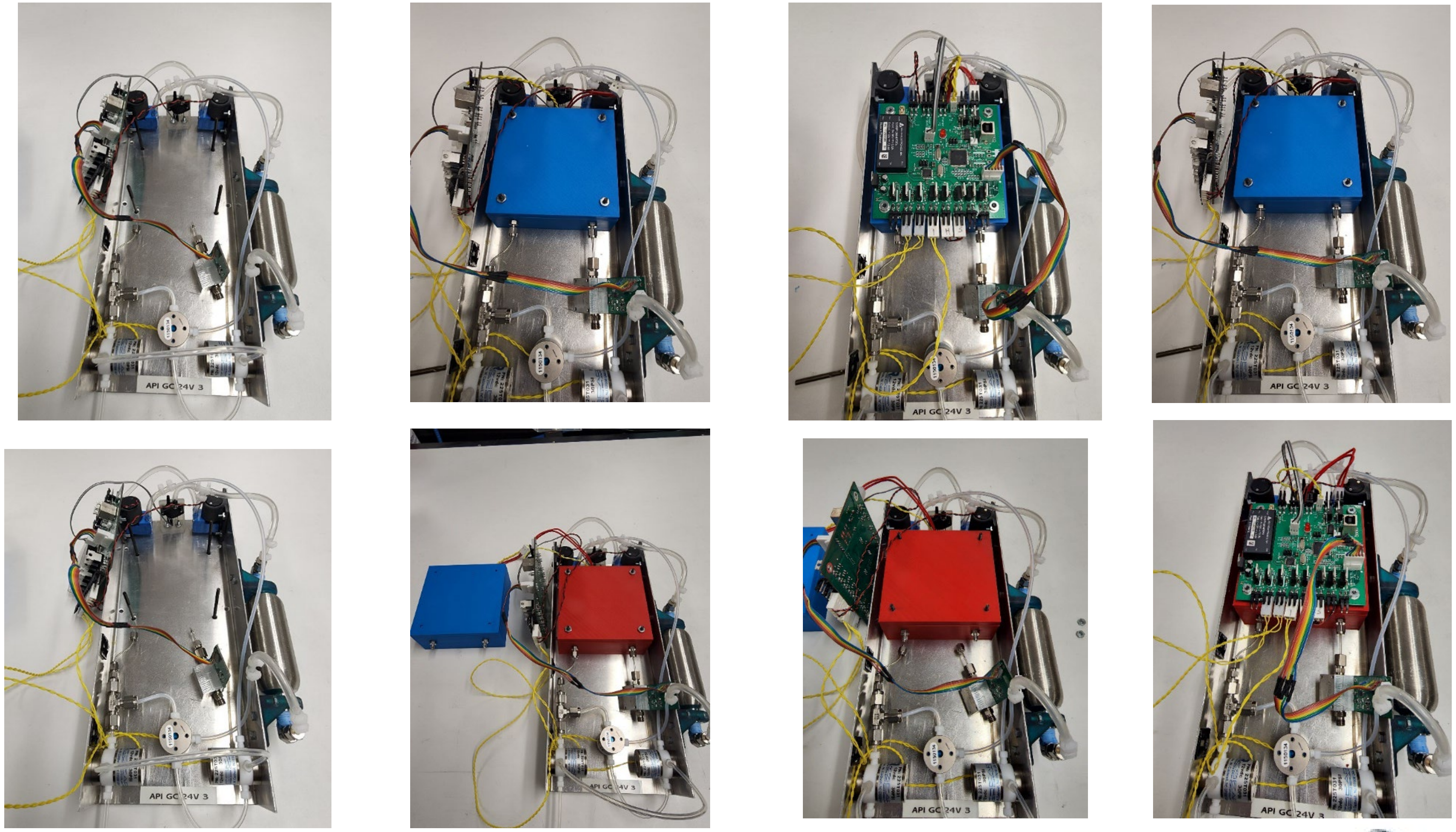
AlumaBOND column in experimental oven. Targeting light hydrocarbons C1-C5.

MXT-Q-BOND column. Targeting permanent gases.

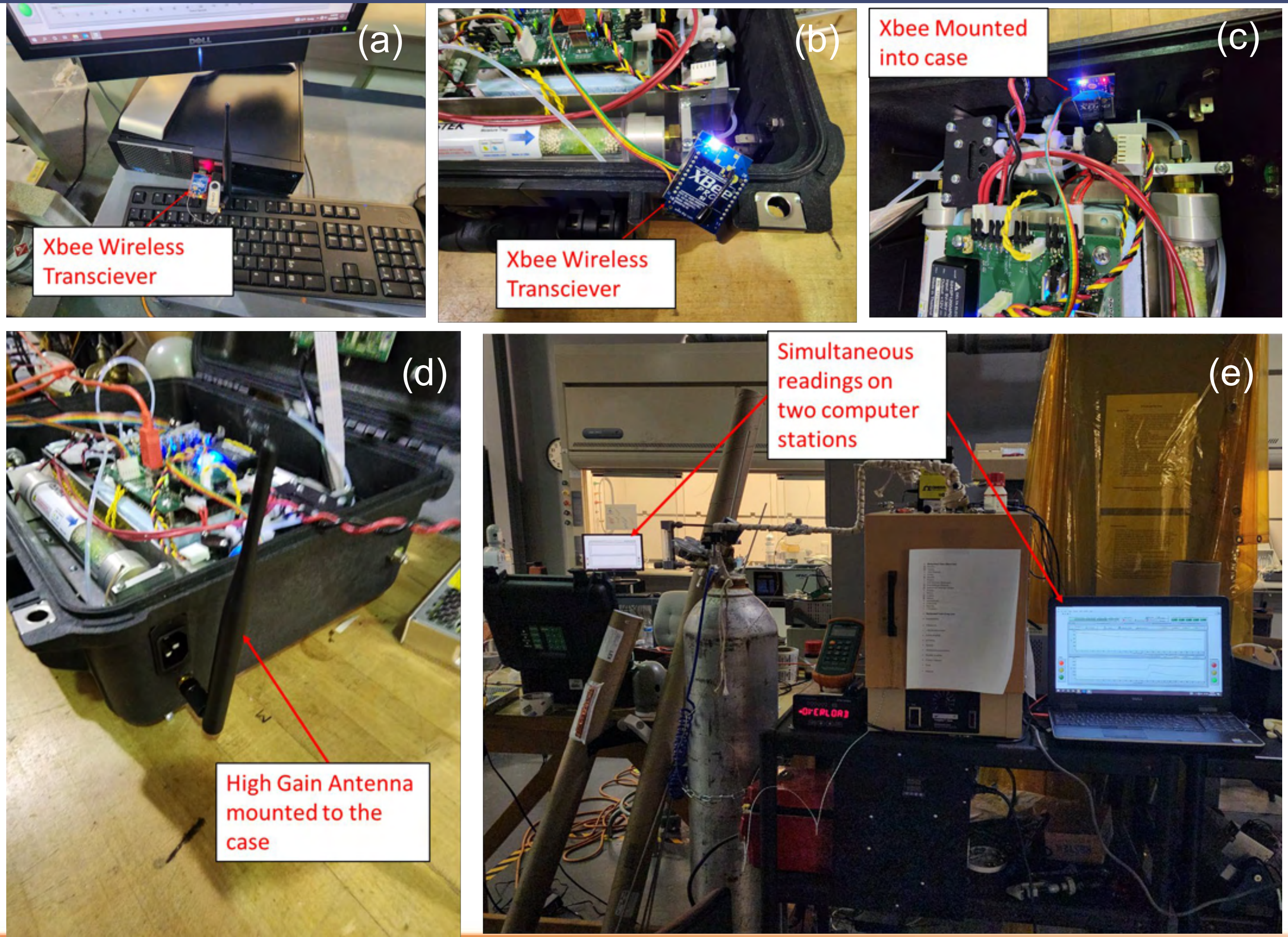


MXT-WAX column. Wide range column.

Modular Design: Quick Column Swap

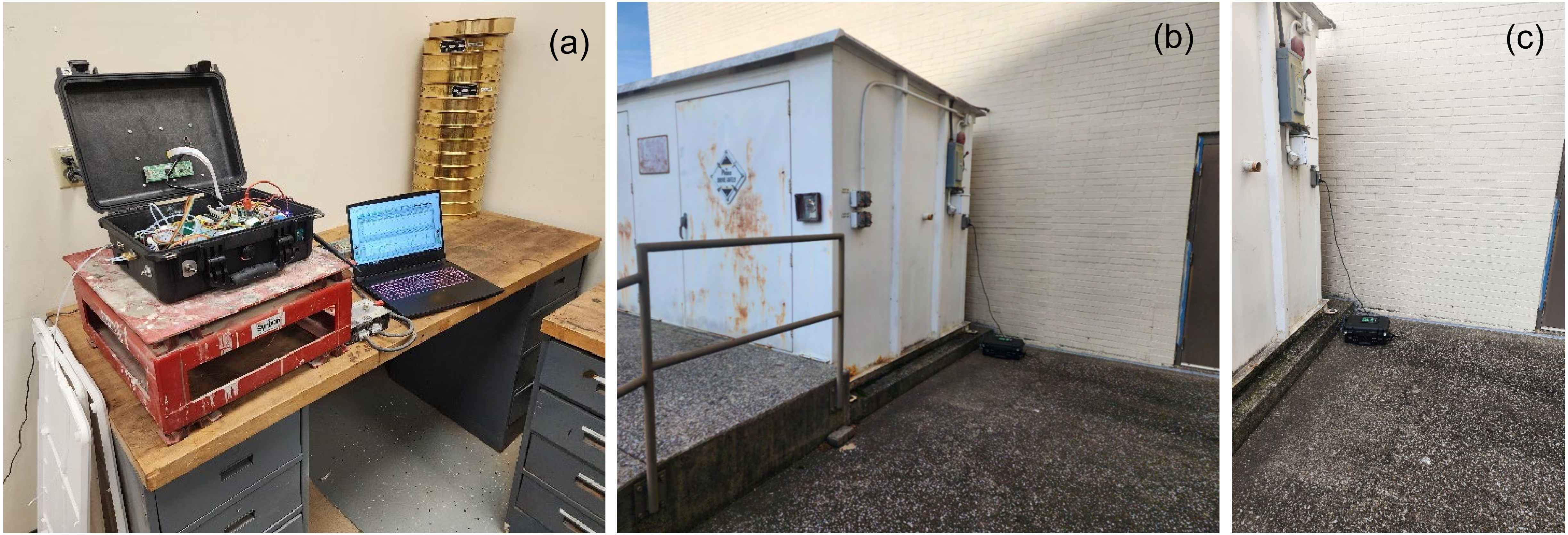


Modular Design: Wireless Communication



- An Xbee module mounted to a USB carrier board **(a)**.
- An Xbee module is also attached to the GC controller board and mounted into the case. **(b, c)**.
- High gain antennas have been attached to the pelican case as well as the receiver module **(d)**.
- Data is exactly mirrored on both the USB and Xbee computers **(e)**.

Environmental Tolerance Testing under Vibration (a) and Fluctuating Temperature and Humidity (b, c).



Transition to Industrial-Grade Design: Structural Optimization

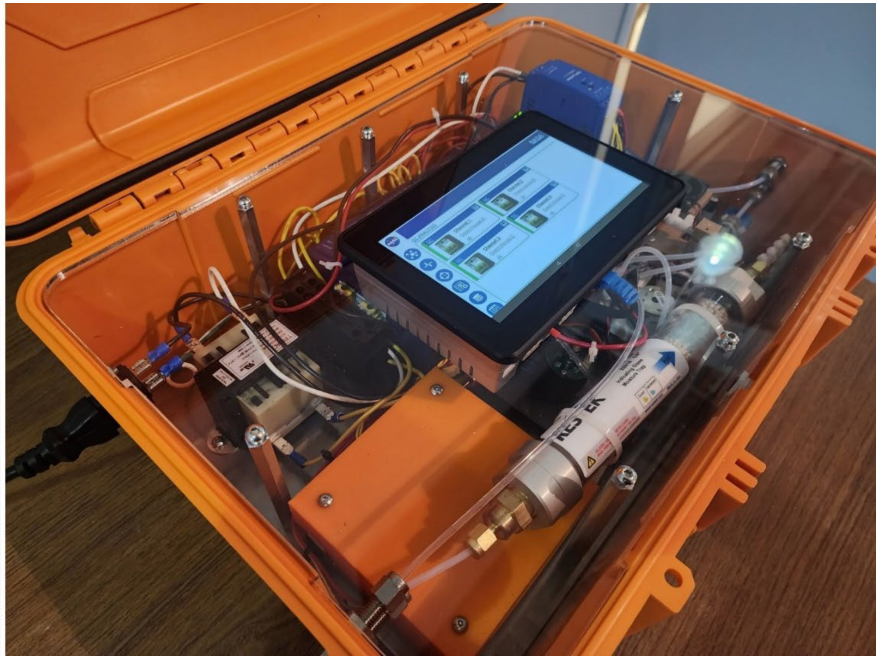
- Currently, our instruments are being transitioned from computer-based systems to controller-based ones.
- The industrial grade secure Distech controller naturally replaced Raspberry Pi computer, which operates as the open-source ecosystem.
- Novel industrial grade control platform (Distech, ECY303-M3) for Adelphi leak detector was designed to provide universal control solution for device operation, web interface, automated calibration, data integration, process automation, and multi-point sampling.

Transition to Industrial-Grade Design: Compact Stationary System

Web Interface: Web interface provides human to machine interface (HMI) through a web App or web browser. Currently, any mobile device with web browser can be used for control of the instrument.

Automated Calibration: The process of system calibration can be performed using a portable calibration system. The system consists of two channels (zero air and calibration gas of known concentration) connected to a gas mixing chamber.

Transition to Industrial-Grade Design: Portable System

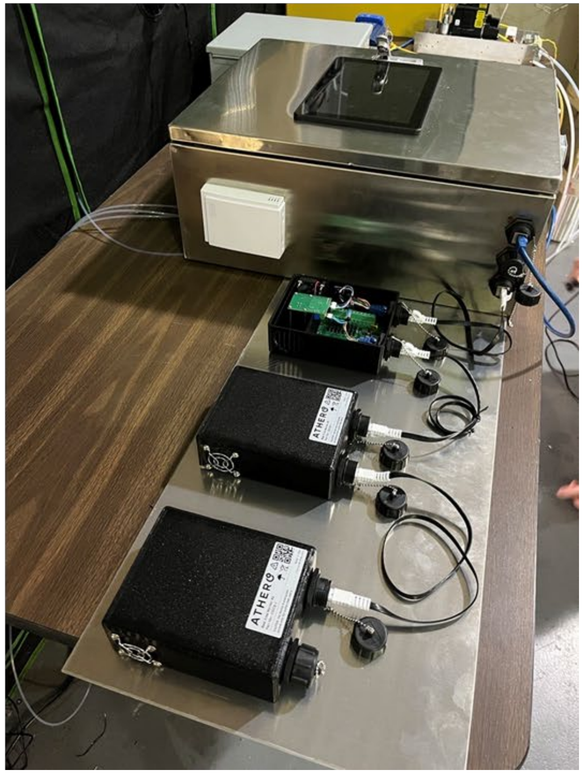


Process automation: The system is fully automated and samples chemicals, conducts measurements and reports the status without any involvement of an operator. Manual control from a remote location is also available as an optional feature.

Multi-point detection inside and outside the cargo area: The Distech controller supports communication with up to four remote modules ECx-Light which could be installed at distance of hundred meters from main controller. Each module enables monitoring from four independent locations. For the current design maximum amount for sampling units is equal to 16 (4x4).

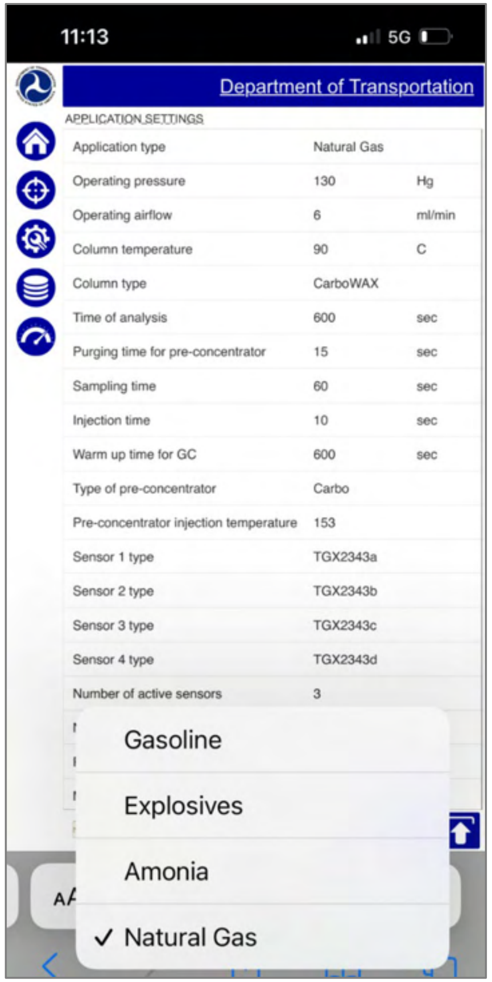
Industrial-Grade System for Monitoring of Autonomous Vehicles

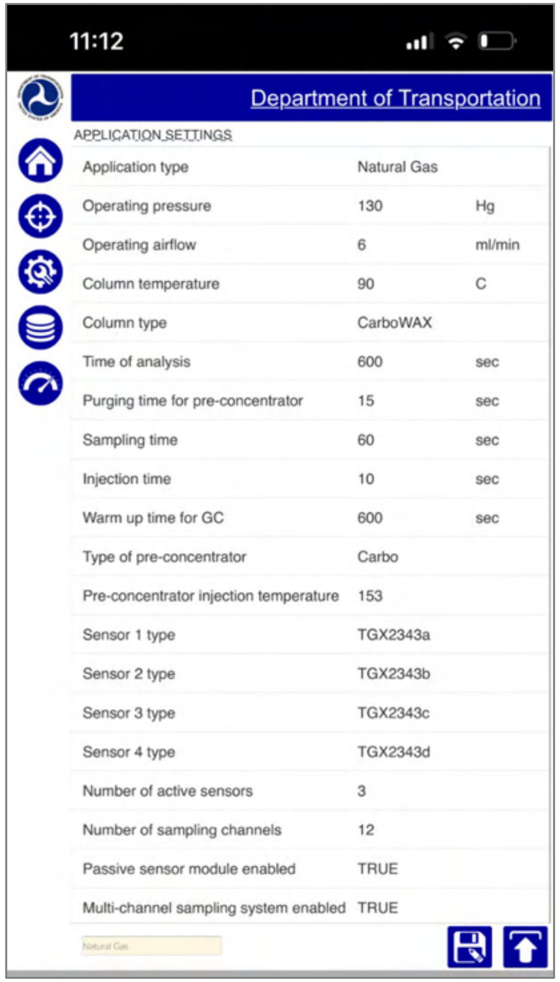


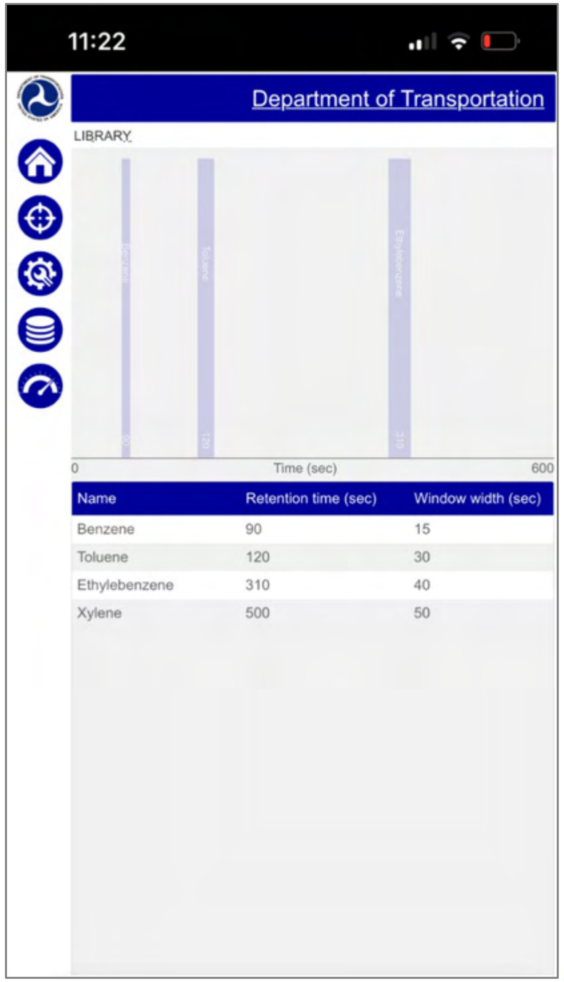


Industrial-grade system for monitoring of autonomous vehicles: compact GC used as communication hub for real-time sensors and equipped with the multichannel sampling system.

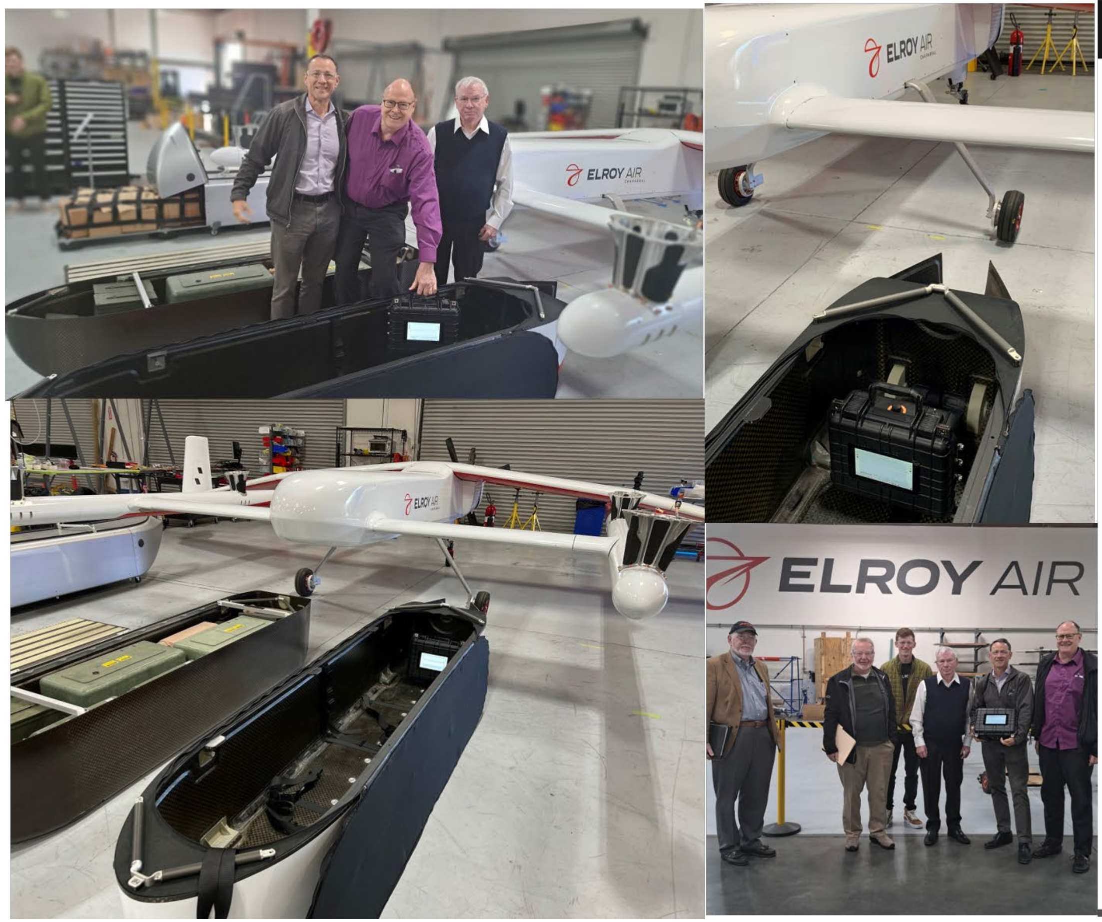
Mobile Interface

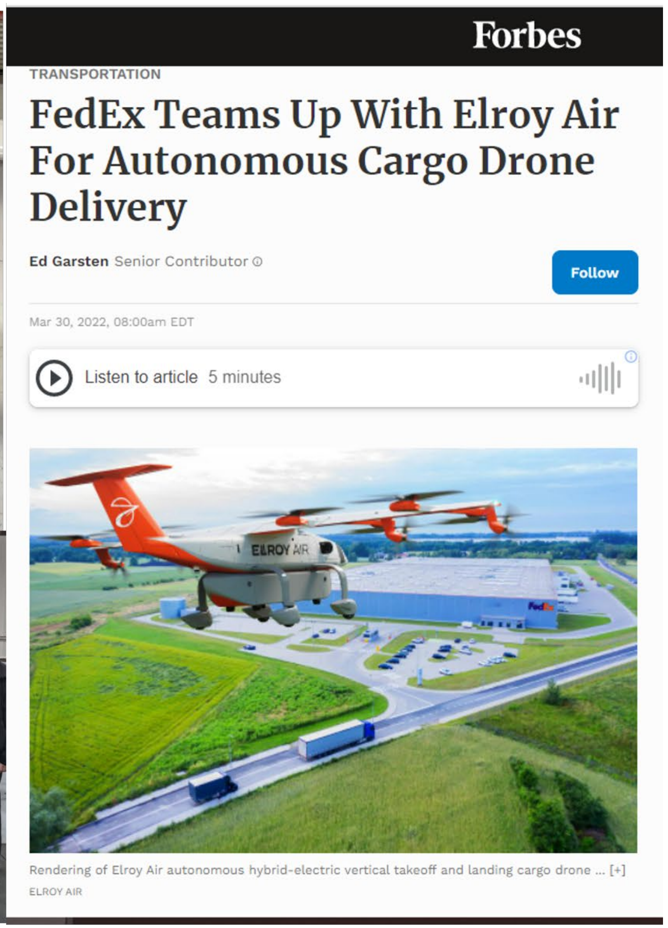






Field Testing





Forbes

TRANSPORTATION

FedEx Teams Up With Elroy Air For Autonomous Cargo Drone Delivery

Ed Garsten Senior Contributor

Follow

Mar 30, 2022, 08:00am EDT

Listen to article 5 minutes

Rendering of Elroy Air autonomous hybrid-electric vertical takeoff and landing cargo drone ... [+]

ELROY AIR

- Adelphi is working with Elroy Air on the system implementation.
- Elroy Air is currently working with FedEx on autonomous cargo drone delivery.

Contact Information

Adelphi Technology Inc.

2003 E. Bayshore Road Redwood City, CA 94063

CGary@adelphitech.com

+1 (650) 474 2750

THANK YOU!

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

LNG by Rail Quantitative Risk Assessment and Worst Case Analysis

November 28, 2023

LNG by Rail QRA and WCA Agenda

- Introduction
- Scope and Purpose
- Quantitative Risk Assessment
- Worst Case Analysis
- Results
- Discussion

LNG by Rail QRA & WCA

- May 2022 PHMSA Contracted with ABSG Consulting Inc. (ABSG)

- Scope:
  - Perform Quantitative Risk Assessment and
  - Worst-Case Scenario Analysis of LNG Transport by Rail Car

- Prompted by TRB Report titled "Preparing for LNG by Rail Tank Car: A Review of U.S. DOT Safety Research, Testing, and Analysis Initiative."

National Academies of Sciences, Engineering, and Medicine. 2021. *Preparing for LNG by Rail Tank Car: A Review of a U.S. DOT Safety Research, Testing, and Analysis Initiative*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26221.

Risk Model

Basic Risk Model = Frequency × Probability × Consequence

FREQUENCY		PROBABILITY		CONSEQUENCE
Frequency of accident at a specific location	× Probabilities of various number of cars involved	× Probabilities of various release sizes from a various number of tank cars	× Probabilities of event types (e.g., fires, BLEVEs) resulting from various LNG release sizes	× Consequence fatality estimates for all release sizes & event types

- **Frequency** is the likelihood of a given accident per train transit
- **Probability** is the likelihood of various event types resulting from various LNG releases
- **Consequence** is the estimated fatalities
- **Risk** is the estimated fatalities per train transit

Modeling Approach:

- Employed QRA best practices to estimate
  - (1) accident frequencies,
  - (2) conditional probabilities, &
  - (3) consequences - based on Worst Case Analysis (WCA)
- Leveraged previous QRAs & authoritative references to support methodology
- Developed & implemented geospatial model using national rail network & high-definition population data for estimating impacts on populations

Train Types	Operations	Representative Routes
1. Unit trains 2. Manifest trains	1. Loading & unloading 2. Transit 3. Switching (manifest trains only)	1. Tioga, ND to Boston, MA 2. Tioga, ND to Jordan Cove, OR 3. Wyalusing, PA to Boston, MA 4. Seminole, TX to Corpus Christi, TX

Train characteristics

Unit Train Configuration

Type	Count	Position(s) in Train
Locomotives (head end)	4	1-4
Buffer car	1	5
LNG tank cars	100	6-105

Manifest Train Configuration

Type	Count	Position(s) in Train
Locomotives (head end)	4	1-4
Buffer cars & other railcars	5	5-9
LNG tank cars	20	10-29
Rail cars	76	30-105

Assumptions

- 105 car length
- 4 locomotives (212.5-ton weight each) for mainline operations
- 143-ton weight for LNG & all other types of rail cars
- 1st LNG tank car in manifest trains at position 10 (6th position from last locomotive)

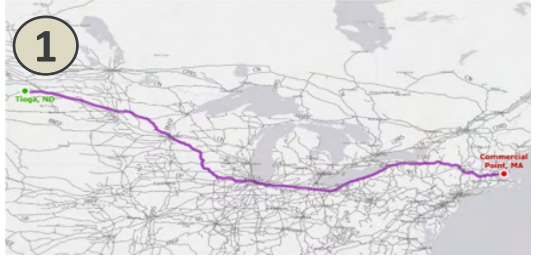
Representative Route Characteristics

Route	Origin		Destination		Length (miles)
	City	Location	City	Location	
1	Tioga, ND	Alkane Midstream LLC Tioga ND	Boston, MA	Commercial Point LNG Plant	1,998
2	Tioga, ND	Alkane Midstream LLC Tioga ND	Jordan Cove, OR	Jordan Cove LNG Plant	1,460
3	Wyalusing, PA	Wyalusing PA	Boston, MA	Commercial Point LNG Plant	430
4	Seagraves. TX	Alkane Midstream LLC Seminole TX	Corpus Christi, TX	Corpus Christi Liquefaction Plant	721

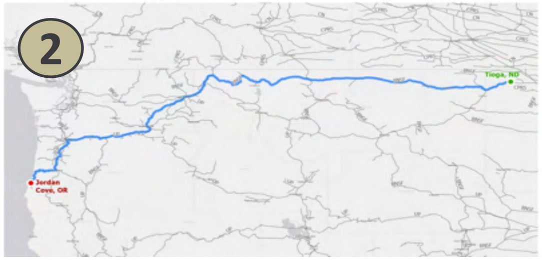
Route	FRA Track Class					% of Route Signaled	% of Route with >20 MGT Traffic Density
	1	2	3	4	5		
1	2%	1%	7%	52%	38%	88%	85%
2	7%	2%	7%	22%	63%	86%	91%
3	6%	3%	45%	40%	6%	67%	9%
4	11%	2%	19%	65%	4%	68%	70%

- Route track characteristics inferred from FRA accident & crossings inventory data
- Speed of operations set to allowed track class limit with a maximum allowable speed of 50 mph

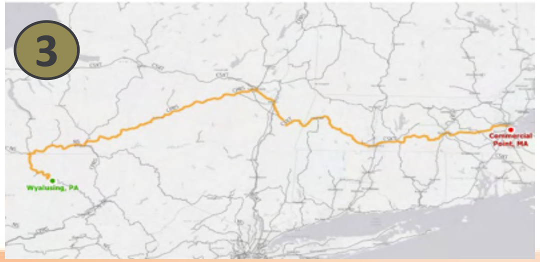
Bakken Region, ND to Boston, MA



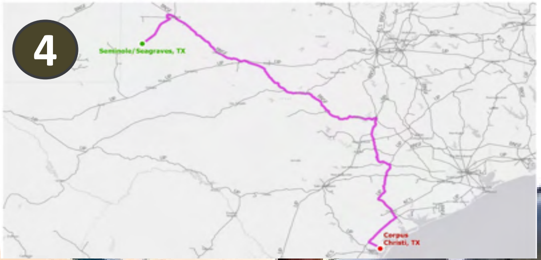
Bakken Region, ND to Coos Bay Area, OR



Wyalusing, PA to Boston, MA



Permian Basin, TX to Corpus Christi, TX



Risk Calculations by Operation

Loading & Unloading

Frequency, consequence, and risk calculated at origin and destination points

ORIGIN DESTINATION

\+

Transit

Frequency, consequence, and risk calculated for each segment of the route. Segmentation based on:

- Natural breakpoints based on track characteristics that affect accident frequency & release probabilities
- Spacing of points for consequence calculation (100 m)

ORIGIN DESTINATION

Risk calculated for each route segment

Route segmentation for factors affecting accident frequency

Route segmentation for consequence calculation points

Consequence calculated at equally spaced points along route (100 m)

\+

Switching

Frequency, consequence, and risk calculated at origin, destination, and switching yards (manifest trains only)

ORIGIN DESTINATION

Yard switching location

=

Route Risk

Risks by operation added for overall route risk

ORIGIN DESTINATION

Accident Frequency & Release Size Probability Modeling

MODELING FACTORS

- Accident types
- Train characteristics
- Route characteristics
- Track types
- Speeds of operations
- Tank car characteristics
- Speed-dependent conditional probability of release estimates
- Loading/unloading factors

OPERATIONS & ACCIDENTS

- Loading/ Unloading Accident
- Transit Derailment
- Transit Collision
- Switching Accident

Accident Frequencies

- Transit derailment based on track class, signalization, & traffic density: location specific rates
- Transit collision rate: 29 collisions/1B train miles
- Yard switching accident rates for manifest trains: 6.43 derailments/1M cars processed
- Loading/unloading accident rate calculated based on: (1) piping, hose, valve, & pump failure, (2) operator connection error & (3) inadvertent movement of cars during transfer: 1 release/25K transfers

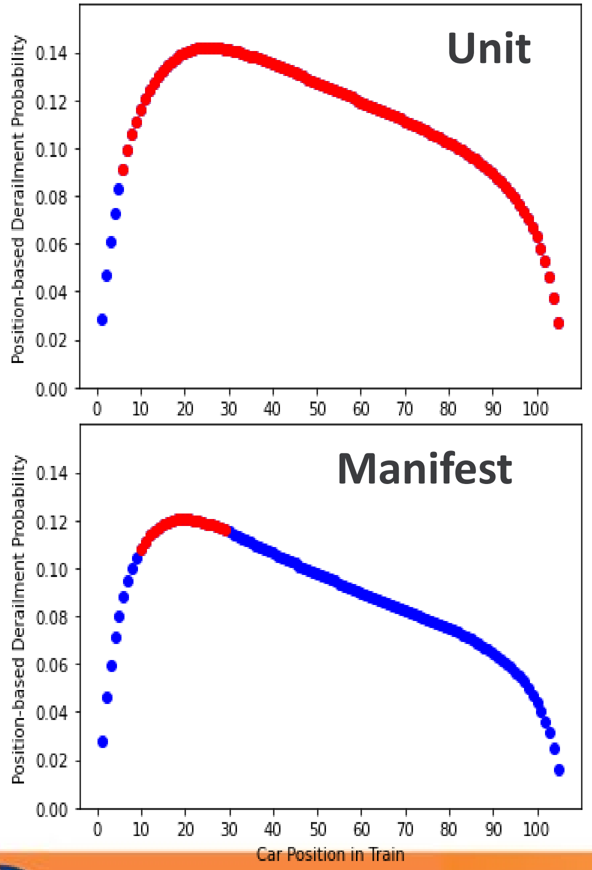
Traffic density (MGT)	Signaling	FRA Track Class				
		1	2	3	4	5
<20	Non-signaled	4.9E-06	1.9E-06	1.0E-06	5.9E-07	0.0E+00
	Signaled	7.4E-06	2.0E-06	8.1E-07	4.2E-07	7.3E-07
>=20	Non-signaled	8.4E-07	6.0E-07	2.2E-07	2.9E-07	0.0E+00
	Signaled	1.2E-06	6.6E-07	2.6E-07	1.4E-07	7.8E-08

Route	Route	Derailment Rate Per Trip & Train Mile
1	Tioga, ND - Boston, MA	2.3E-07
2	Tioga, ND – Jordan Cove, OR	3.8E-07
3	Wyalusing, PA – Boston, MA	9.7E-07
4	Seagraves, TX – Corpus Christi, TX	7.4E-07

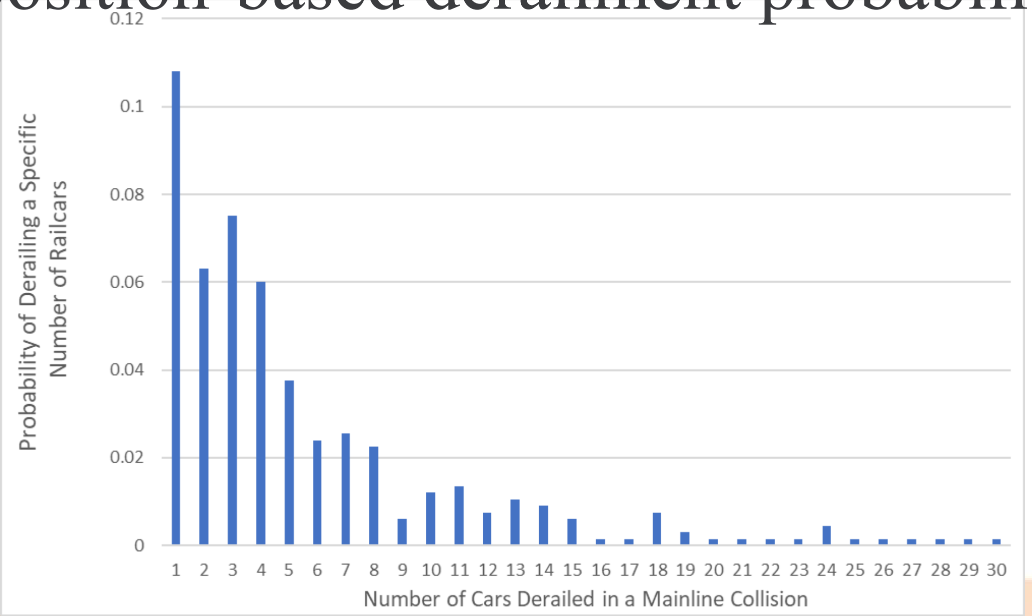
Probabilities of Various Number of Cars Involved

POSITION-BASED DERAILMENT CONDITIONAL PROBABILITY

26-mph derailment example

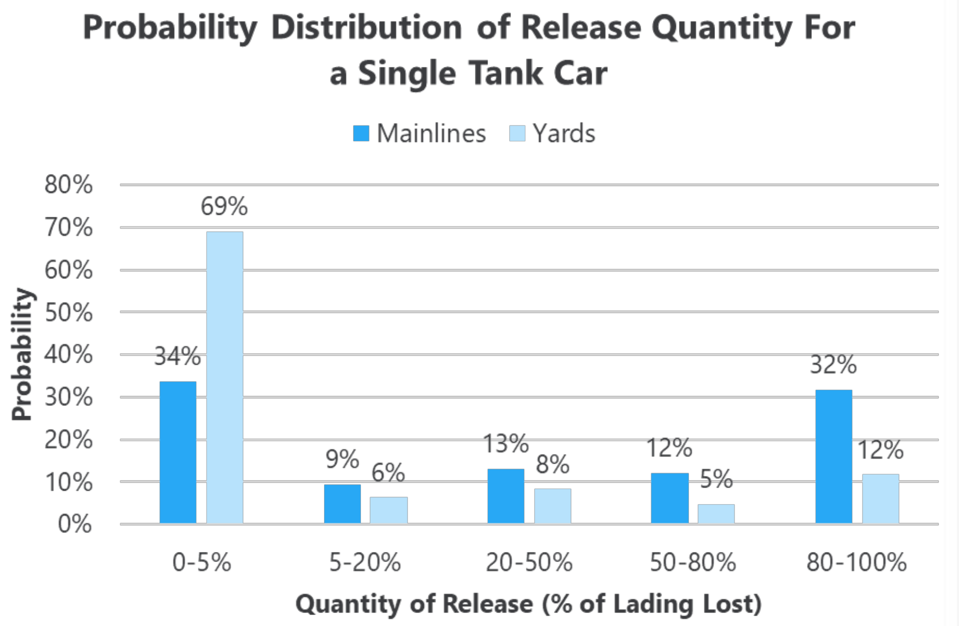


- Considers the probability of derailment starting at a certain position
- Probability contributions of several rail cars being derailed from each of the positions to determine the position-based derailment probability



Representative Release Sizes

- RA-19-01 : *Conditional Probability of Release (CPR) Estimates for Railroad Tank Cars in Accidents* provides probability of release size from a single tank car for both pressure and non-pressure cars for transit & switching
- Applied to choose 10 representative release size categories for transit & switching operations



Transit & Switching Release Sizes	
1. ½ car	6. 3 cars
2. 1 car	7. 4 cars
3. 1.5 cars	8. 5 cars
4. 2 cars	9. 6 cars
5. 2.5 cars	10. 7 cars

CPR determination

- CPR for LNG tank car design 113C120W9 is unknown
- Probability estimates for release sizes leverage RA-19-01 informed by:
  - Tank car design information, TRB study, FRA impact test
  - Operational characteristics: train speed & track type
- Method was not directly applicable to cryogenic tank cars, but estimates derived for two cases:
  - **Coarse conservative:** outer tank-only
  - **Coarse approximation:** tank with a combined thickness of the inner & outer tanks

TANK CHARACTERISTICS

- TC128B steel type
- 9/16-inch outer tank thickness
- 0.375-inch inner tank thickness
- Full head shield & jacket

CPR Case	Speed (mph)		
	25	40	50
Coarse conservative	0.07	0.09	0.11
Coarse Approximation	0.03	0.04	0.05

Risk Model

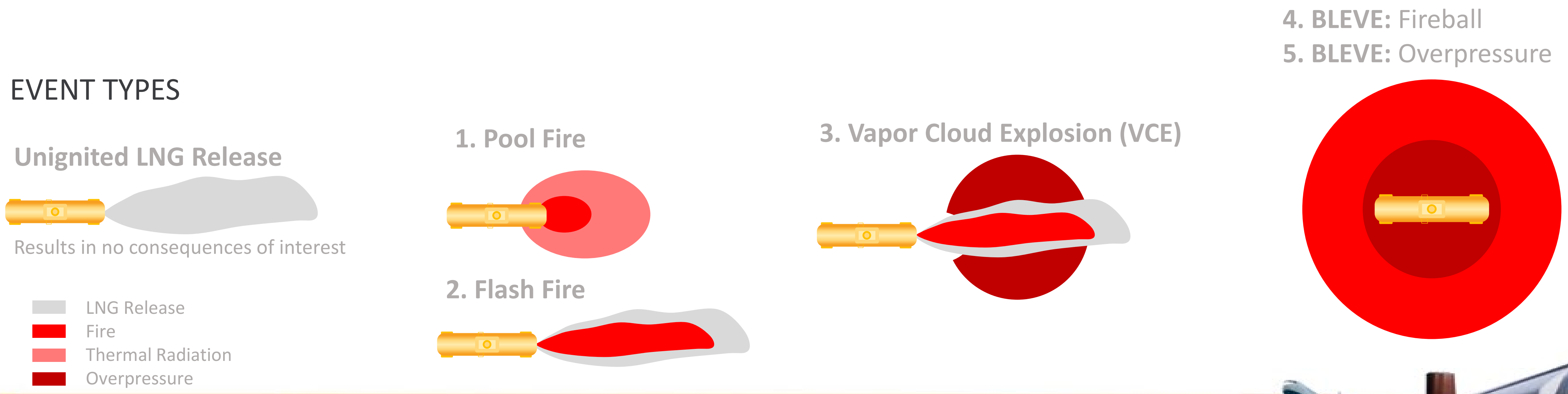
Basic Risk Model = Frequency × Probability × Consequence

FREQUENCY		PROBABILITY		CONSEQUENCE
Frequency of accident at a specific location	Probabilities of various number of cars involved	Probabilities of various release sizes from a various number of tank cars	Probabilities of event types (e.g., fires, BLEVEs) resulting from various LNG release sizes	Consequence fatality estimates for all release sizes & event types

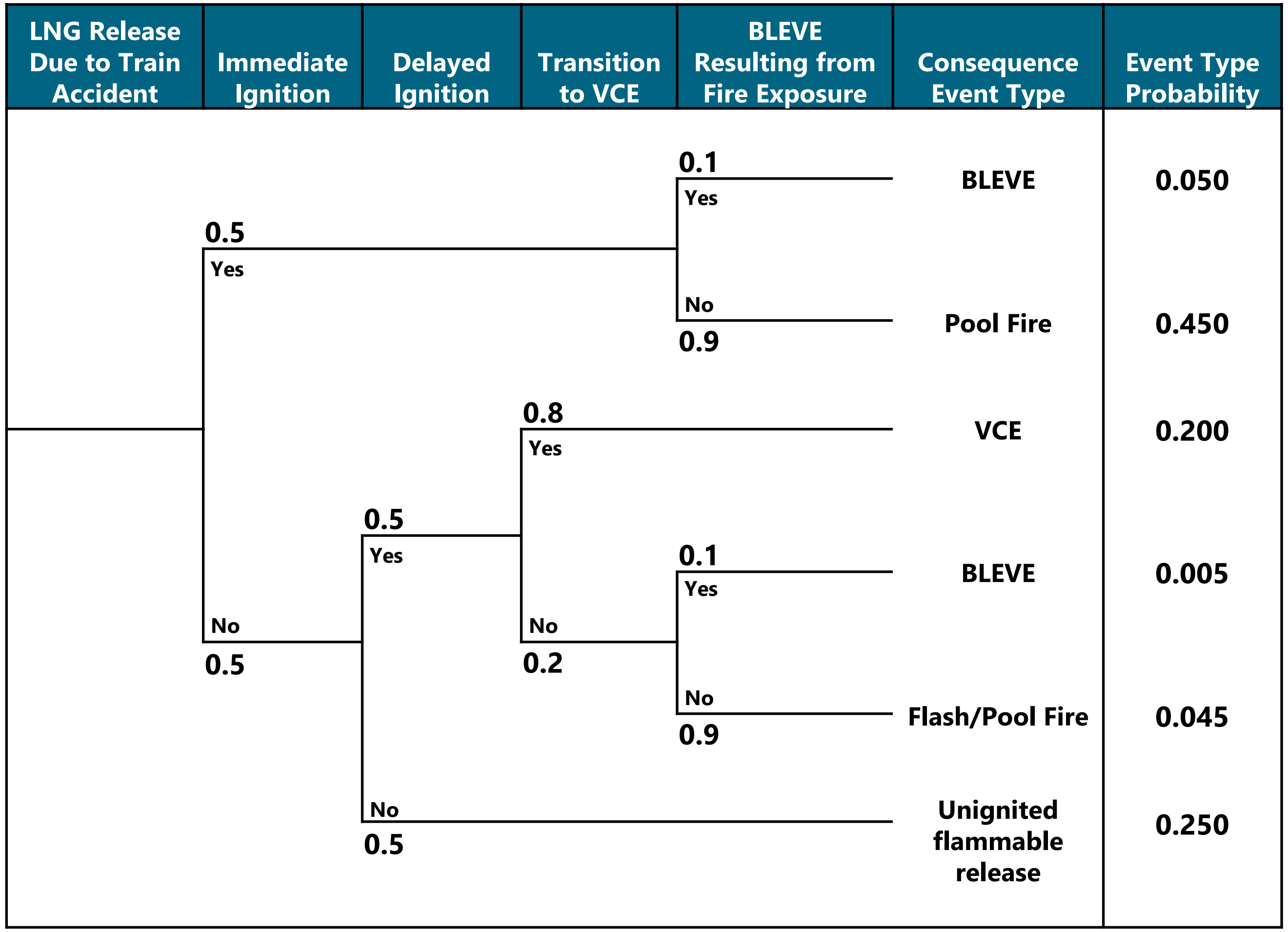
- **Frequency** is the likelihood of a given accident per train transit
- **Probability** is the likelihood of various event types resulting from various LNG releases
- **Consequence** is the estimated fatalities
- **Risk** is the estimated fatalities per train transit

Event Trees & Event Types

- Event trees used to describe the 5 event types
- Branch point probabilities defined the probability for each potential event type
- Probability estimates came primarily from other HazMat rail transport & hydrocarbon facility operating experience & failure data



Transit & Switching Event Tree



BRANCH POINT CONSIDERATIONS

- **Immediate ignition**
  - Includes ignition by sources in area & by the train accident itself
  - Using Hazard Class 2.1 rail accident data to inform this, plus comparison to published values
- **Delayed ignition**
  - Using suggested data from published studies
  - Also considering insights from Hazard Class 2.1 rail accident data
- **Transition to VCE**
  - Very likely outcome in more densely populated areas (e.g., houses, businesses, people)
  - Congestion/confinement contributes to the transition
  - Uses value consistent with published sources
- **BLEVE from fire exposure**
  - Considers lessons learned from worst case analyses
  - Uses value consistent with published sources; however, with limited data, a conservative value was selected.

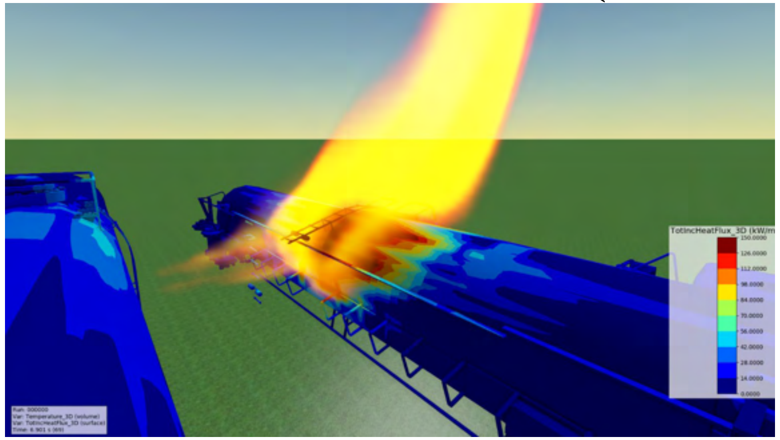
LNG by Rail WCA

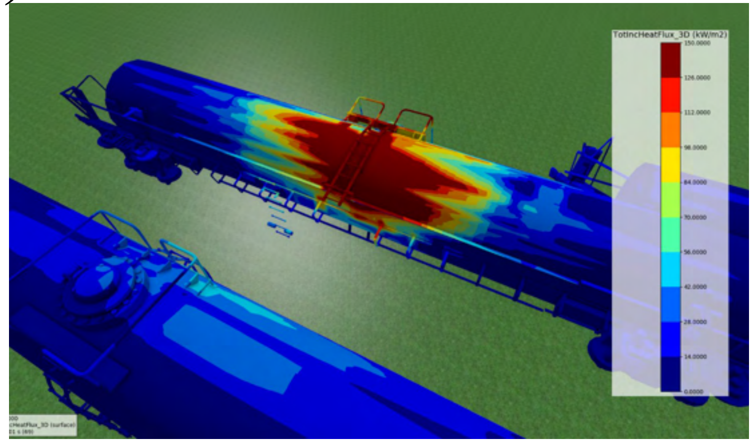
Define accident scenarios that consider the most severe in the event of an accident involving the transportation of LNG via rail.

- Task 3: Jet Fire Heat Flux on Adjacent Tank
- Task 4: Valve or Line Damage Leak Consequences
- ~~Task 5: Cascading Tank Damage Due to Impinging Unignited LNG Pools~~
- ~~Task 6: Cascading Tank Damage Due to Heat Flux from Pool Fire~~
- Task 7: Rapid Phase Transition (RPT) Risk to First Responders
- Task 8: Vapor Cloud Explosion (VCE) Hazards from LNG Vapors in Congested/Confined Spaces
- Task 9: BLEVE

LNG by Rail WCA Task 3 – Jet Fire Methodology

- Scenario: Overturned car in a fire relieving via PRDs which are directed toward another tanker (Jet Fire Impingement)



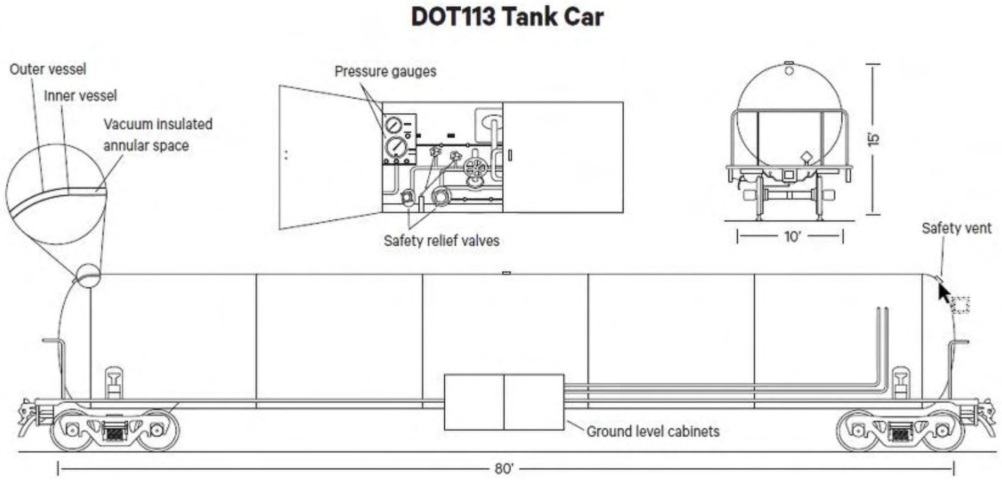


- Horizontal Jet Fire will release liquid LNG at its saturated temperature at the PRD setpoint pressure (75 psig PRD x 1.21 per API standards).
- Ignition is assumed given tanker is heated by an external fire that heats the outer-most cylindrical shell.
- Max 250 kW/m2; 10 ft wide section > 200 kW/m2, 23 ft wide section > 100 kW/m2

LNG by Rail WCA Task 4 – Valve/Line Leak Consequences Methodology

•Modeling Assumptions:

- 3” valve leak
- Assume tank car pressure remains constant during release
- Pressure of 45 psig was used in previous TRB modeling The start to discharge pressure of the pressure relief valve is 75 psig.



Leaks from damage to the valve box or lines result in flammable vapor clouds, fires, and explosions

Task 7: Rapid Phase Transition Methodology

- Focus on RPT Risk to First Responders
- Three LNG compositions were analyzed; lean, design, and rich
  - Large puncture leaks (12” x 12”) will empty a railcar in 55 sec and the pool will be vaporized after 2 min; therefore, RPT is not a risk for responders (occurs too fast)
  - Smaller leaks (3” valve) will create a RPT hazard for up to 20 min
  - Consequences from RPT are based on the TNT equivalent from work energy performed during the liquid to gas isentropic expansion

Alkane	Lean	Design	Rich
Methane	0.9797	0.9668	0.9318
Ethane	0.0137	0.0256	0.05
Propane	0.0012	0.0018	0.0089
n-Butane	0.0054	0.0058	0.0093

Distances are not significant; approaching an LNG pool this close would be a more significant fire risk should ignition occur

[1] Aursand, E., Hammer, M., “Predicting triggering and consequence of delayed LNG RPT”, Journal of Loss Prevention in the Process Industries, Sept. 2018.

Task 8: VC Hazards - LNG Vapors in Cong. Areas Methodology

- Puncture of 7 railcars used in the WCA
- The multi energy method was used to predict overpressure and impulse
- Congestion assumptions for a rural and urban scenarios
  - The rural scenario will have 3% congestion with an average diameter of 6 in
  - The urban scenario will have 5% congestion with an average diameter of 4 in
- Spill pools were assumed to have an 8” thickness due to topography and drainage; maximum pool radius was 115 ft

Task 9: BLEVE Methodology

- Occurs when a vessel heats up and fails with liquified gasses temperatures well above ambient bubble points
- 2 cases
  - Case 1: 100% full, 300 psig rupture (minimum burst pressure of tanker), assumes the PRDs are ineffective
  - Case 2 50% full; 75 psig PRD * 1.21 factor (API)
- Surface emissive power of the fireball assumed 508 kW/m2 (per TRB recommendation)
- CCPS equations used to calculate fireballs; FACET3D (ABS) used for blast effects
- BLEVE is considered a low probability event given the tanker design (double wall insulation) and recent testing experience

Fatality Summary

Task	Description	Hazard	Maximum Fatalities	
			Urban Day	Urban Night
3	3" valve leak	Flash fire	29	1
		VCE	27	187
		Jet fire	108	5
		Pool fire	223	20
8	7 puncture derailment	Flash fire	70	2
		VCE	1325	424
		Jet fire	*	*
		Pool fire	335	28
9	BLEVE	Overpressure	419	75
		Fireball	540	27

*Jet fires from a 12”x12” puncture are unlikely at the pressures considered; the large release rate will quickly reduce the tank pressure and the leak momentum will decrease to a spill which forms a pool

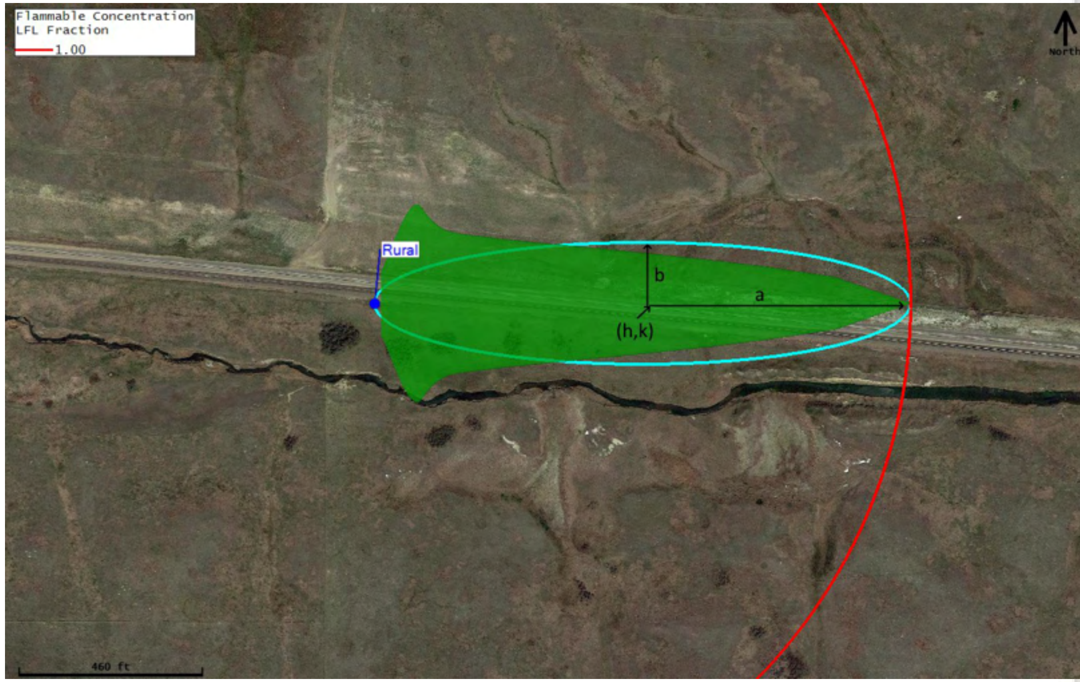
Conclusions

Task 3: Jet fire impingement on adjacent tank

Failure not predicted but MLI will see high temperatures

Task 4 & 8: LNG leaks (3” valve and multiple punctures)

- Flammable clouds (flash fires)
  - The flammable clouds can be 100’s of feet to over 1000 ft long and cover a significant area
  - Largest populations (daytime and urban) don’t align with the largest cloud sizes (night time and rural)
  - Flash fire hazards produced the lowest maximum fatality estimates of all the hazard type considered



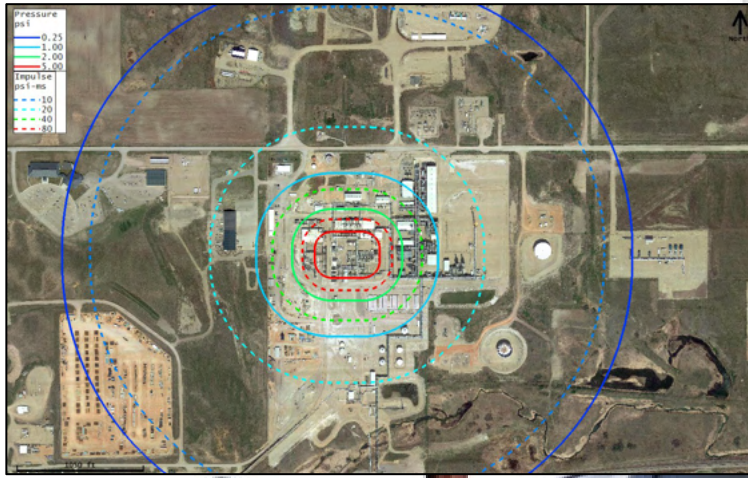
Conclusions (Tasks 4 & 8)

Vapor Cloud Explosions

- The 3” valve leak VCEs only produce significant fatalities in the Urban Night case
- The 7 puncture derailment VCEs are significant due to the large cloud sizes and they result in very strong explosions
- The VCE event has the highest fatality estimates; however, the probability that a derailment causing 7 punctures does not immediately ignite the release is low

Pool Fires

Likely overestimates fatalities for fires in urban environments as model does not consider exposure duration or potential escape indoors or shield behind buildings



Conclusions

Task 7: Rapid phase transition

- RPT of LNG can create small overpressure events equivalent to 5 to 12 lb of TNT
- The lethality distance for these events was calculated to be around 15 ft (for 10% lethality)
- At this distance, 1st responders are at higher risk from fire should the spill ignite

Task 9: BLEVE

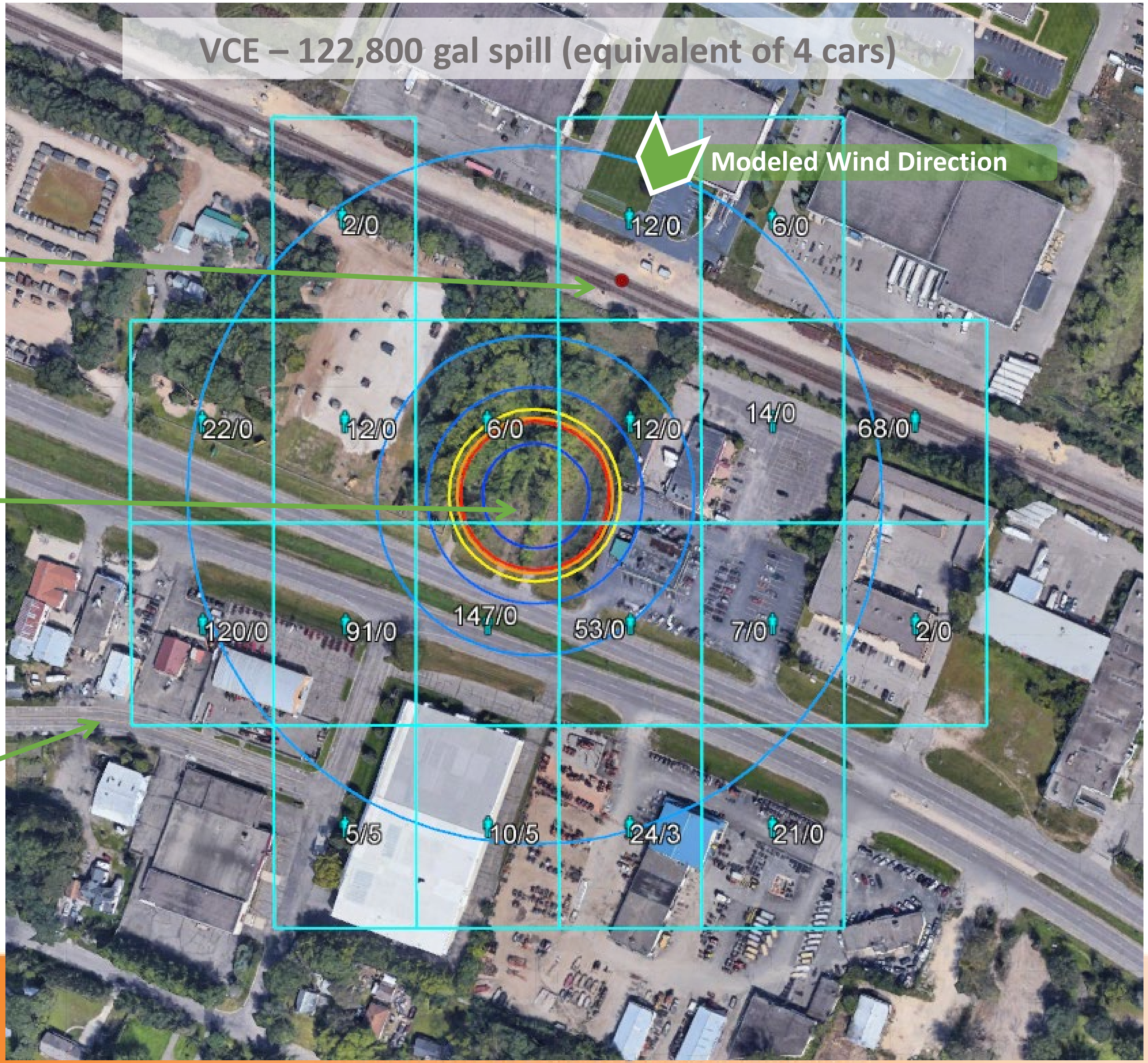
- Considered unlikely due to the double walled tank car design and prior tank car test
- BLEVE takes a long duration fire exposure before the explosion allows for evacuation of the nearby populace
- Should a BLEVE occur, consequences from overpressure can be severe
- Fireball fatalities can be very high, but this is unlikely since people will move away from the burning tank car and/or find shelter inside a building.

Population overlay for fatality estimation

Release point

Center of blast based on downwind travel of flammable vapor

LandScan™ cells with day/night population counts



Estimated Fatalities	
Maximum wind direction (NNE)	
Day	38.1
Night	0.1
Average of 16 wind directions	
Day	16.9
Night	0.02
Average of day/night fatalities	
Day/Night	**8.5**

Population Distribution	
Day	93% Indoors
Night	99% Indoors

Indoor exposure zones

- 60.5%
- 37.1%
- 13.7%
- 2%

Outdoor exposure zones

- 90%
- 40%
- 5%

Results presented in 7 dimensions

Routes

- 1. Tioga ND to Boston MA
- 2. Tioga ND to Jordan Cove OR
- 3. Wyalusing PA to Boston MA
- 4. Seminole TX to Corpus Christi TX

Train Types

- Unit
- Manifest

Operations

- Loading/Unloading
- Transit
- Switching

Risk Categories

- Very Low (< $1x10^{-8}$)
- Low ($1x10^{-8}$ to $1x10^{-7}$)
- Medium ($1x10^{-7}$ to $1x10^{-6}$)
- High ($1x10^{-6}$ to $1x10^{-5}$)
- Very High (> $1x10^{-5}$)

Event Types

- Pool Fire
- Flash Fire
- BLEVE Fireball
- BLEVE Overpressure
- Vapor Cloud Explosion

County Population Categories

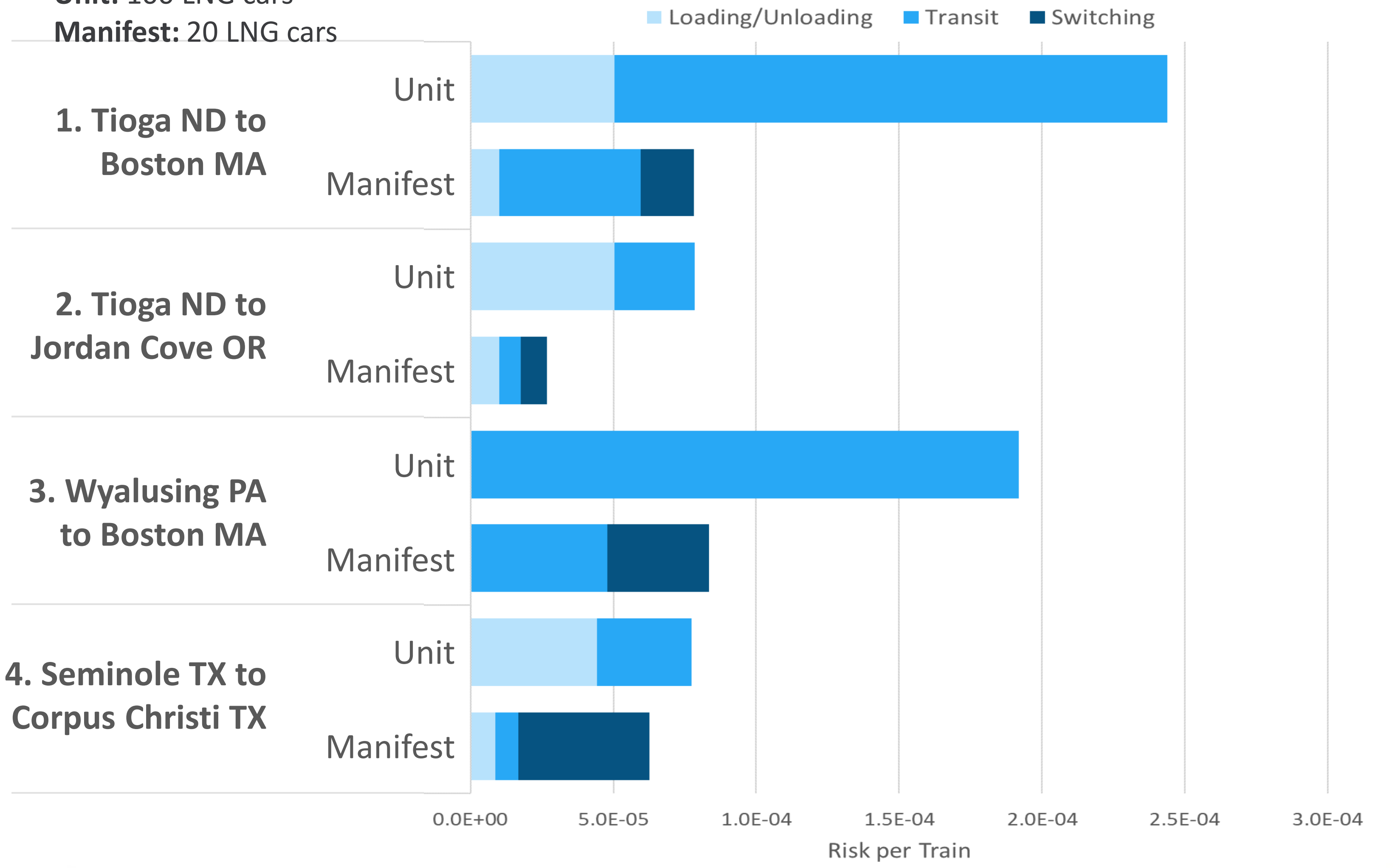
- <2500 people
- 2500 to 20K people
- 20K to 250K people
- 250K to 1M people
- >1M people

Social Vulnerability Quartiles

- Low (0-25%)
- Low to Medium (25-50%)
- Medium to High (50-75%)
- High (75-100%)

Risk per train by route, train type, & operation

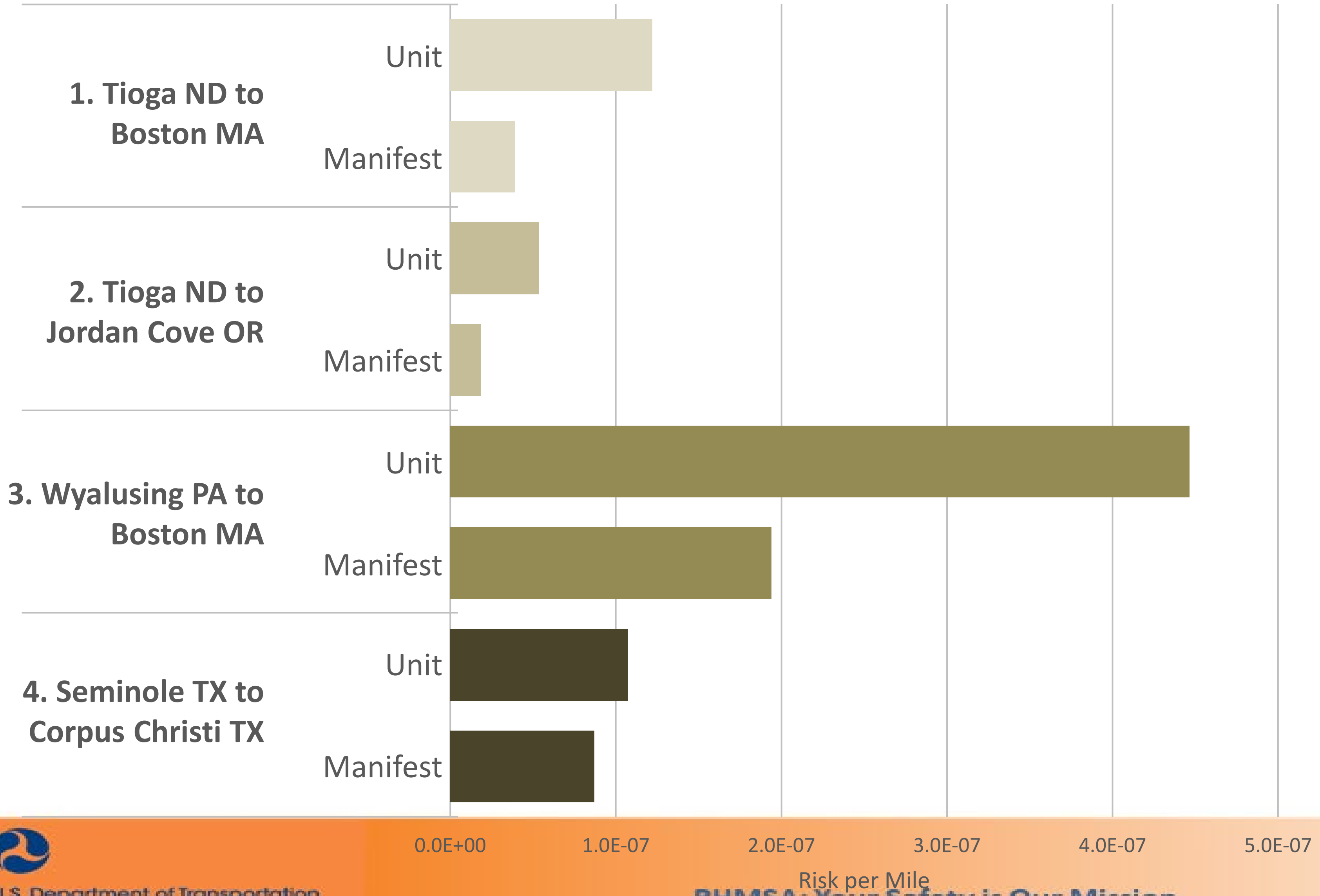
Unit: 100 LNG cars
Manifest: 20 LNG cars



Observations

- Per train, unit is 2.4x higher risk than manifest
- Per car, manifest is 2x higher risk than unit
- Switching ≈ transit risk for manifest trains averaged across routes
- Loading/unloading/ switching risk is highly dependent on location
- Loading/unloading risk contributes 12% of manifest train risk & 25% of unit train risk

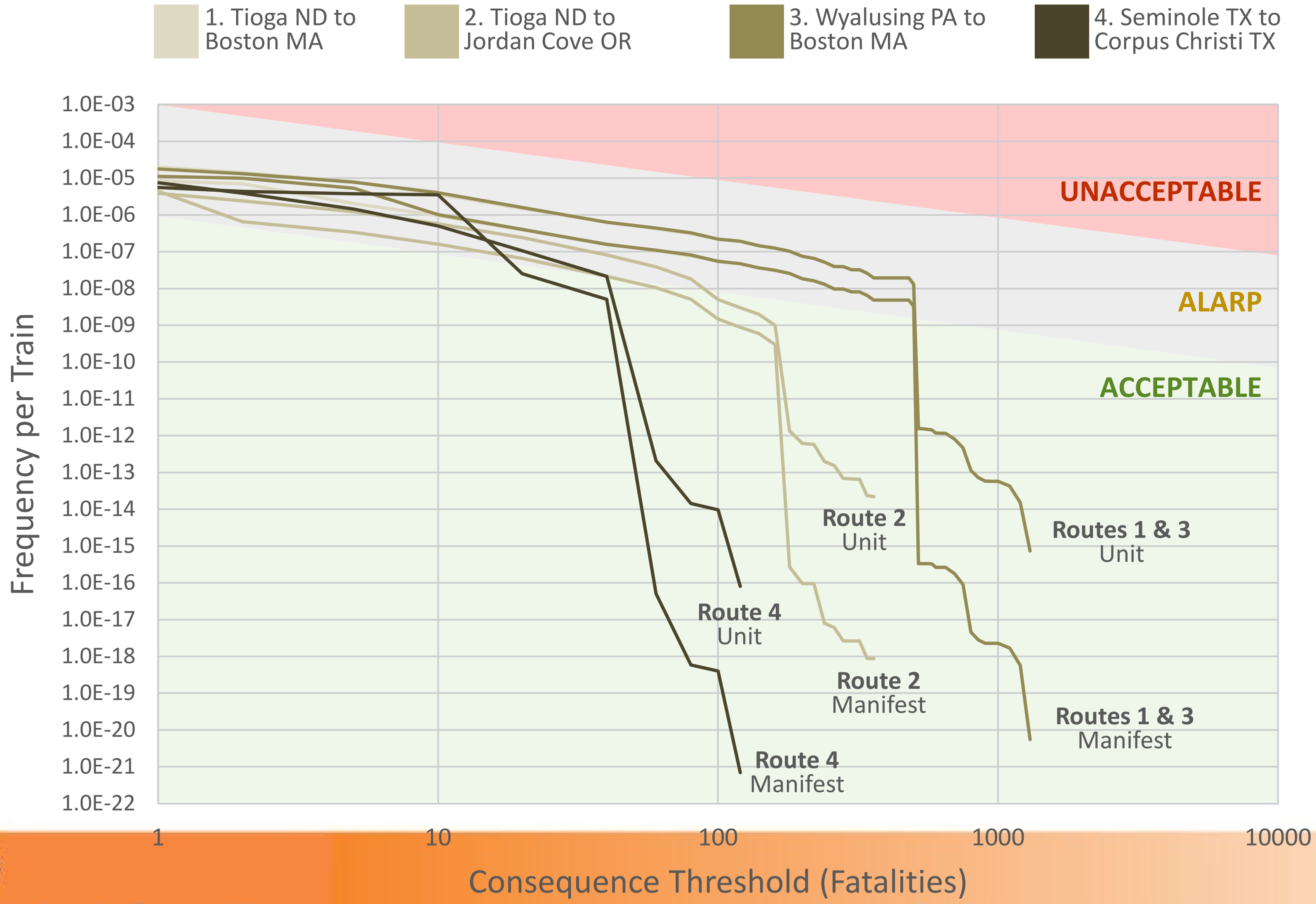
Average risk per mile per train by route & train



Observations

- Route 3 has the highest risk rate due to higher population density in northeast U.S.
- Route 2 has the lowest risk rate due to sparse population in northwest U.S.
- The end of Route 1 is shared with Route 3 but the average is lower due to many more miles in low population areas

F-N curves by route & train type

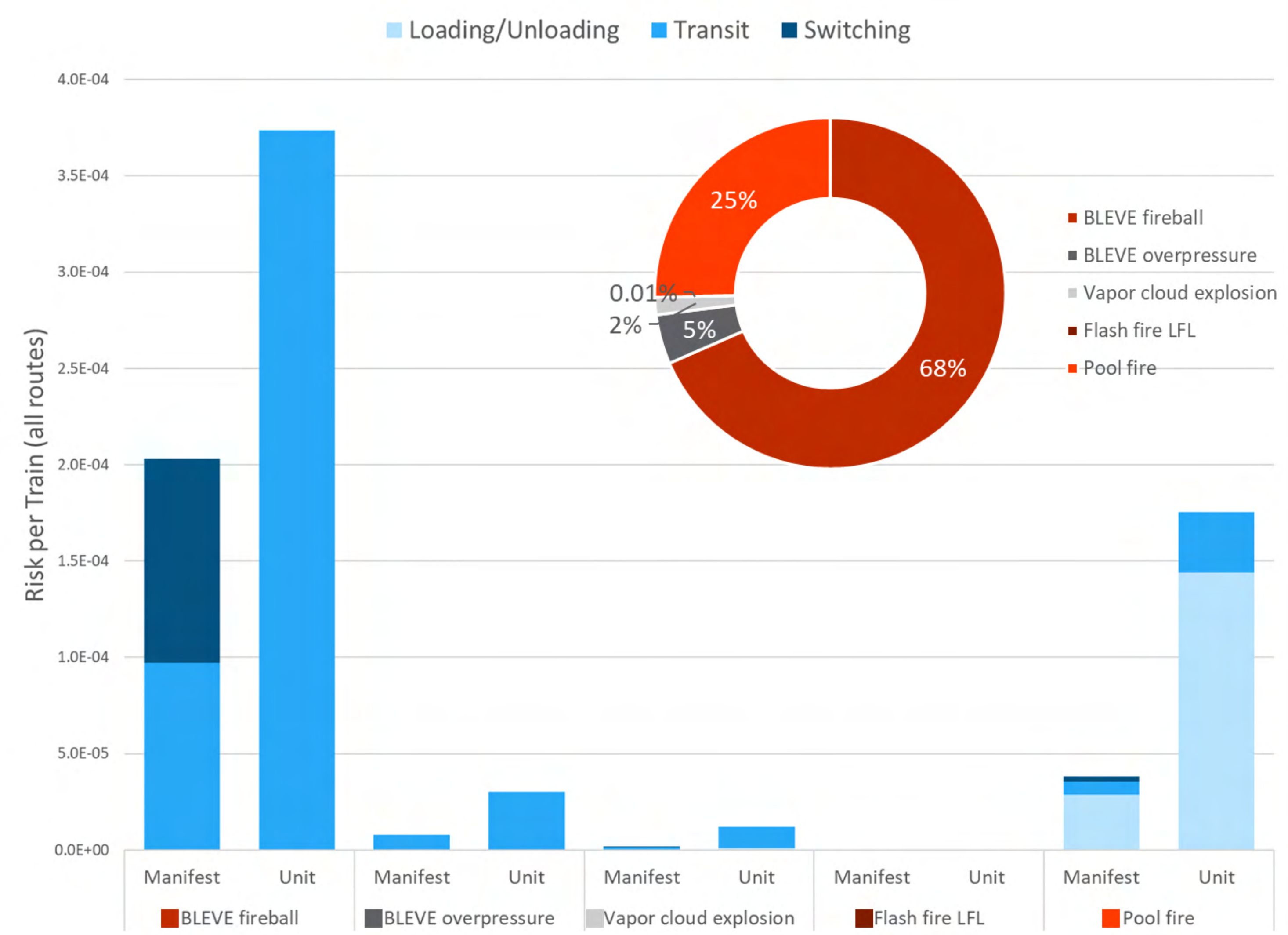


Observations

- All routes and train types fall below the Unacceptable risk threshold
- Unit train risk is higher than manifest train risk
- Risks shown are on a per train basis, Risk Acceptance Criteria typically based on Annual estimates
- **Note:** Routes 1 & 3 have very similar FN curves after ~60 fatality threshold due to similar routing on final leg

Unacceptable, ALARP & Acceptable regions based on report to FRA titled Evaluation of Risk Acceptance Criteria for Transporting Hazardous Materials & NFPA 59A

Risk per train (all routes) by operation, train type



Observations

- The BLEVE fireball event type is the dominant risk driver – it contributes 68% of risk across all routes and train types
- Pool fire is the dominant driver for loading & unloading operations

Route risk for manifest train

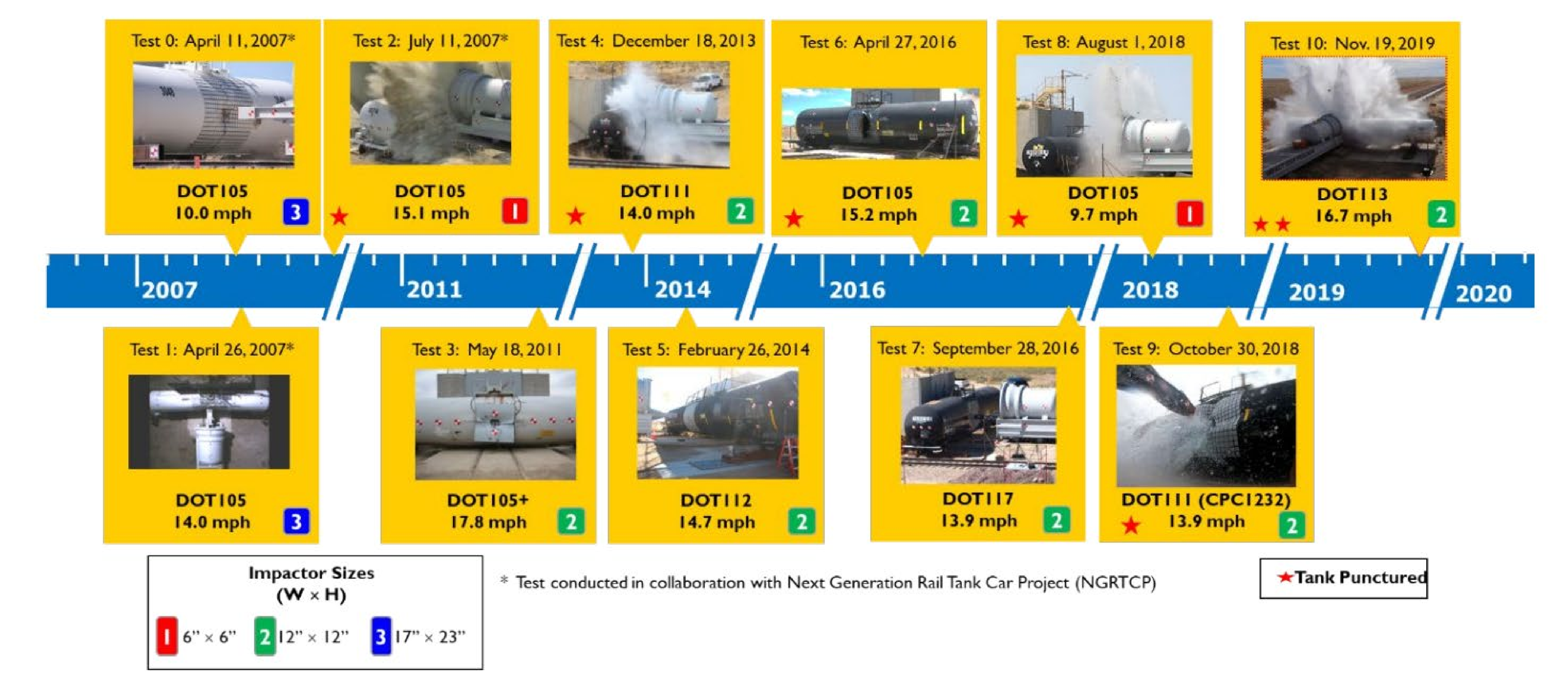
Contact Information

Joseph Myers
ABSG Consulting
jomyers@absconsulting.com

FULL-SCALE SHELL IMPACT IMPACT TEST OF A DOT-DOT-113C120W9 TANK CAR TANK CAR FILLED WITH WITH LIQUID NITROGEN NITROGEN

On May 14, 2022, the Federal Railroad Administration (FRA) conducted a full-scale full-scale shell impact test (Test 13) of a DOT-113C120W9 tank car filled with liquid with liquid nitrogen (LN2). The test aimed to evaluate the puncture resistance of the resistance of the tank car design when subjected to an impact.

BACKGROUND (1/2)



BACKGROUND (2/2)

- HM-264 final rule published July 24, 2020
- Authorizes transportation of LNG in DOT-113C120W9 tank cars
- Additional operational controls

44994 Federal Register / Vol. 8

DEPARTMENT OF TRANSPORTATION

Pipeline and Hazardous Materials Safety Administration

49 CFR Parts 172, 173, 174, 179, and 180

[Docket No. PHMSA–2018–0025 (HM–264)]

RIN 2137–AF40

Hazardous Materials: Liquefied Natural Gas by Rail

AGENCY: Pipeline and Hazardous Materials Safety Administration (PHMSA), Department of Transportation (DOT).

ACTION: Final rule.

SUMMARY: PHMSA, in coordination with the Federal Railroad Administration (FRA), is amending the Hazardous Materials Regulations (HMR) to allow for the bulk transport of "Methane, refrigerated liquid," commonly known as liquefied natural gas (LNG), in rail

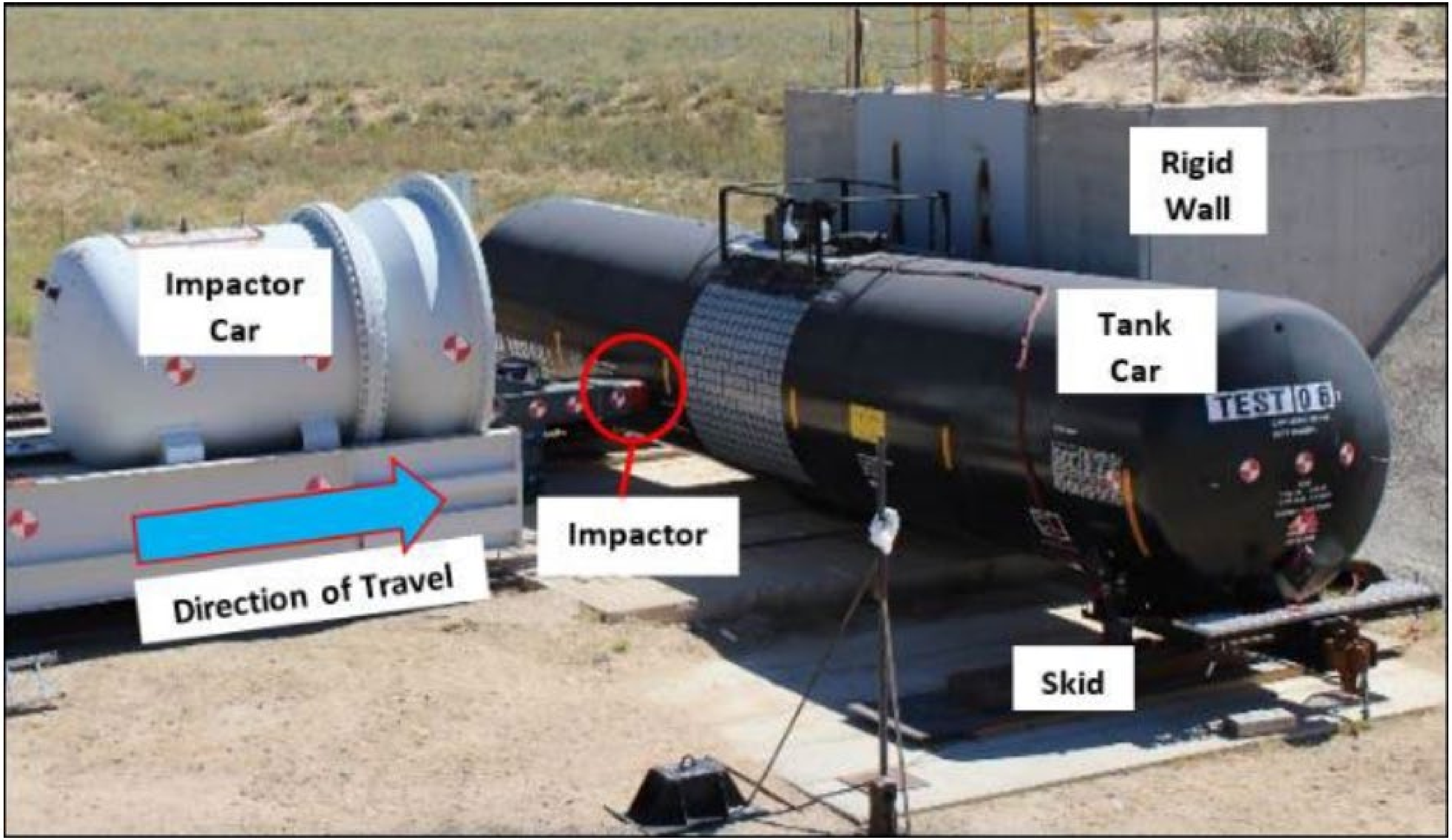
DOT-113 FULL-SCALE IMPACT TESTING PROGRAM

Test #	Test Article	Lading	Impact Speed	Puncture
10	Legacy DOT-113C120W	Water	16.7 mph	Yes
11	Surrogate DOT-113	Water	17.3 mph	No
12	Surrogate DOT-113	LN2	18.3 mph	No
13	New DOT-113C120W9	LN2	22.1 mph	Yes

METHODS

- The shell of the outer tank is struck by a ~297,000-pound ram car equipped with a 12-inch by 12-inch impactor at its mid-height and longitudinally offset ~2.5 feet towards the A-end.

- Various instruments, including laser displacement transducers, pressure transducers, temperature sensors, and string potentiometers, are employed to measure critical parameters during the impact test.


Rigid Wall
Impactor Car
Tank Car
TEST 06
Impactor
Direction of Travel
Skid

CONCLUSION

The newly constructed DOT-113 tank car demonstrated double the peak force and absorbed energy compared to the legacy DOT-113C120W tank car, indicating improved puncture resistance.

FUTURE ACTIONS

- The research team will review the test data, photos, and videos to validate the pre-test finite element (FE) model.
- The model will be updated to reflect the actual impact conditions and used to investigate the puncture resistance of the DOT-113 tank car in real-world service scenarios.

CONTACT ME!

Robert Starin
Chief; Data, Risk, and Analysis
Pipeline and Hazardous Safety Administration
Office of Hazardous Materials Safety
Robert.starin@dot.gov

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

2023 Research, Development and Technology Forum

November 28, 2023

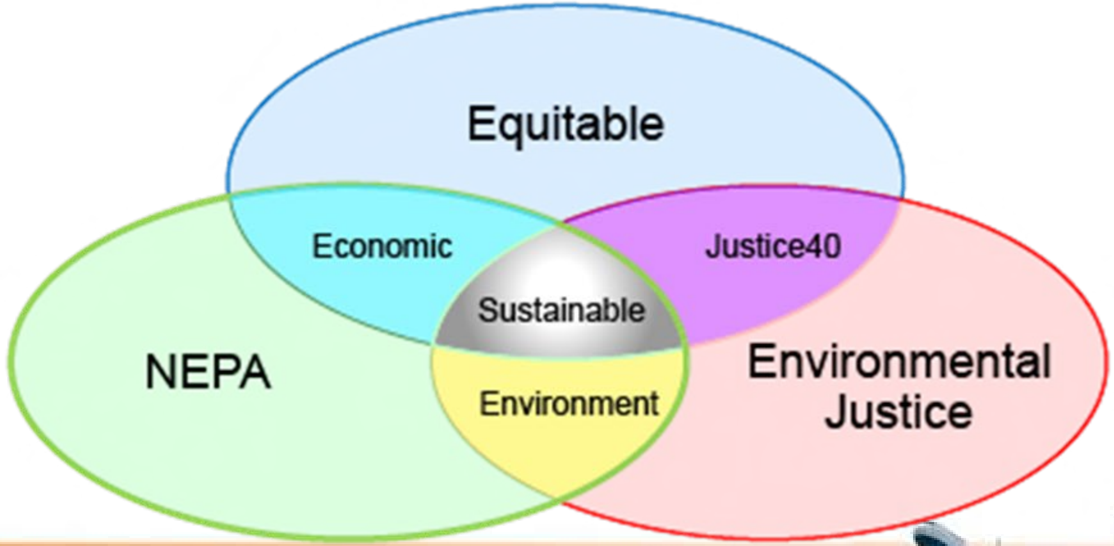
Office of Planning and Analytics (OPA)
Environmental Policy & Justice Division (EPJ)

Carolyn Nelson, P.E., Director

Environmental Justice and Equity Considerations During the Transport of Hazardous Materials

Terminology

Environmental Justice (EJ), Title VI, NEPA and other Non-Discrimination laws, and Equity are distinct elements, collectively they can contribute to the development of an equitable transportation system. These elements are regularly mistaken and used interchangeably, thus, making it essential to understand their differences.



WHAT IS NEPA?

National Environmental Policy Act (NEPA) of 1969

- Edit Master text styles
  - Second level
    - Third level
      - Fourth level
        - Fifth level

What is Environmental Justice (EJ)?

EO 12898 - Executive Order on *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Popu*

On February 11, 1994, President William J. Clinton signed Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations.*

"…each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations…"

EO 12898, Section 1-101

President Clinton signed E.O. 12898 on February 11, 1994

What is Title VI?

Title VI of the Civil Rights Act of 1964

- Prohibits discrimination based on race, color, and national origin in programs and activities receiving Federal financial assistance.

- Provides that "No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance."

Addressing Discrimination under NEPA, EJ and Title VI

NEPA - Responsibility of Federal Agencies to not discriminate. As we conduct NEPA must evaluate our NEPA decisions to ensure actions do not lead to discrimination. As part of the NEPA process evaluate impacts of all actions of the project which includes impacts to EJ and Title VI communities.

EJ – When you have EJ communities, we must evaluate to what extent we have those impacts. (Disproportionately High and Adverse).

Title VI – Prohibits discrimination. Provides a mechanism to file a complaint if stakeholders/public feel federal actions are discriminatory.

NEPA, Environmental Justice & Title VI

WORKING TOGETHER

Equity and Environmental Justice

Biden Administration Executive Orders (EOs)

- EO 13985, “Advancing Racial Equity and Support for underserved Communities Through the Federal Government”
- EO 14008, “Tackling the Climate Crisis at Home and Abroad
- EO 14096, “Revitalizing Our Nation’s Commitment to Environmental Justice for All”

Environmental Justice - Equality vs Equity

Equality

The assumption is that **everyone benefits from the same supports**. This is equal treatment.

Equity

Everyone gets the supports they need (this is the concept of "affirmative action"), thus producing equity.

Justice

All 3 can see the game without supports or accommodations because **the cause(s) of the inequity was addressed**. The systemic barrier has been removed.

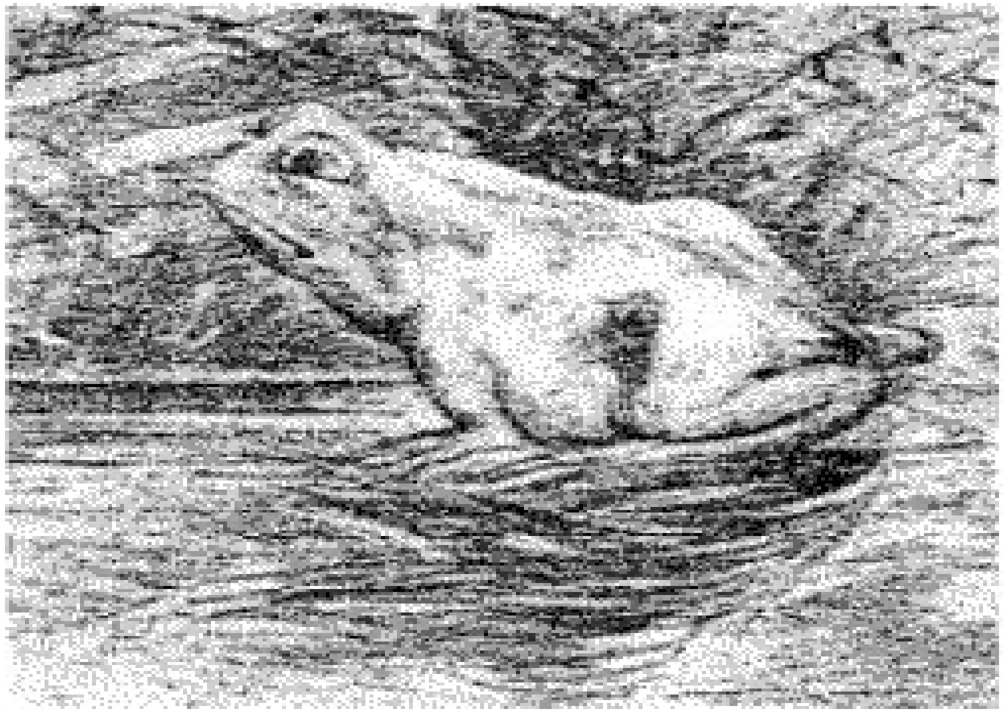
Whole of Government Approach to Addressing EJ & Equity

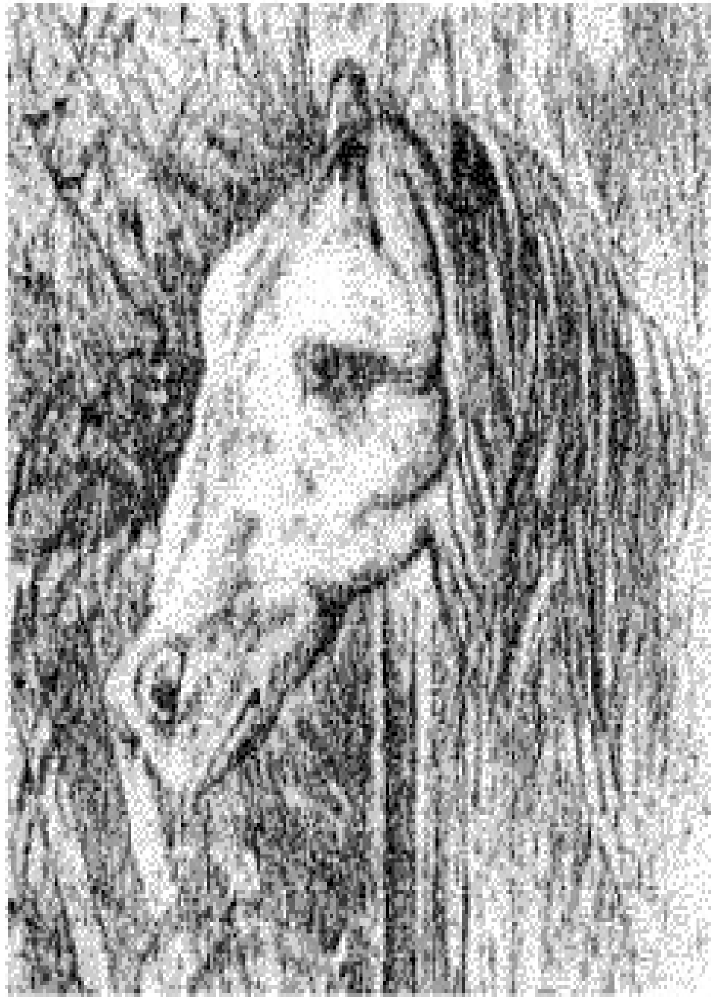
Environmental Justice (EO) 12898, "**Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations"**

Executive Order (EO) 13985, **"Advancing Racial Equity and Support for Underserved Communities Through the Federal Government"** requires the Federal Government to "pursue a comprehensive approach to advancing equity for all, including people of color and others who have been historically underserved, marginalized, and adversely affected by persistent poverty and inequality."

Executive Order (EO) 14008, "**Tackling the Climate Crisis at Home and Abroad,"** seeks to organize and deploy the full capacity of its agencies to combat the climate crisis. This includes a whole of government approach to advance environmental justice. It identifies covered programs and covered investments where "federal investments might be made toward a goal that 40 percent of the overall benefits flow to disadvantaged communities." {Justice40 Initiative }

Executive Order (EO) 14096, **"Revitalizing Our Nation's Commitment to Environmental Justice for All",** seeks to address environmental injustices thru federal governments.





EO 14096 - Executive Order to *Revitalize Our Nation's Commitment to Environmental Justice f*

On April 21, 2023 President Joseph R. Biden, Jr. signed Executive Order 14096, Revitalizing Our Nation's Commitment to Environmental Justice for All

This EO outlines an ambition approach to Environmental Justice that is informed by scientific research, high quality data, meaningful federal engagement with communities, and by consultation with and respect for Tribal Sovereignties, self governments, and respecting cultural practices and indigenous knowledge.

Executive Order 14096 - Confronting Environmental *In*justice

The President's new executive order contains important new charges to agencies to demonstrate leadership and take action to:

1) **Protect overburdened communities from pollution and environmental injustice through stronger action from federal agencies.**

2) **Confronts barriers to community participation in government decision-making.**

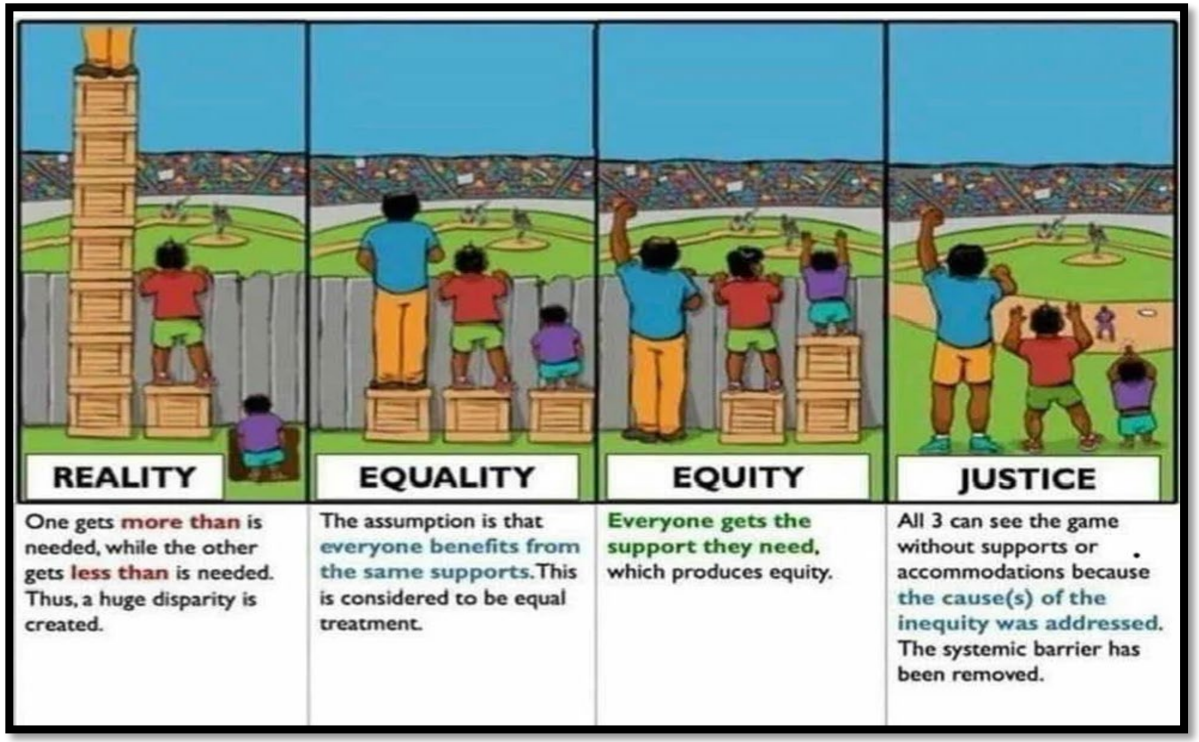
3) **Embed environmental justice for all into the DNA of federal agencies**

Environmental Justice Guidance and Equity

- Developing a PHMSA-specific EJ Strategy
- Equity is the result of Environmental Justice

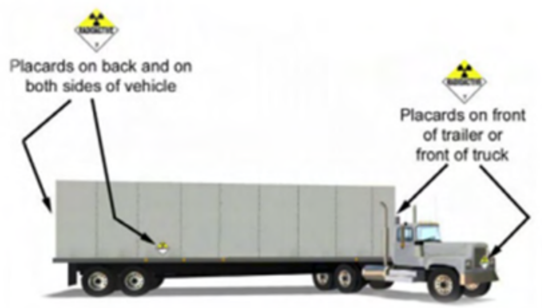
Public Involvement

- Public involvement and a systematic interdisciplinary approach to outreach.
- Agencywide *meaningful* public involvement



RD&T for Environmental Policy and Health Impact Analysis

- Concepts:
  - Health effects of methane emissions
  - Transportation routing for transporting hazardous materials
  - Developing methodology specifically for identifying equity benefits
  - Look into possible cumulative health impacts and how they accumulate over time and events




Thank You

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

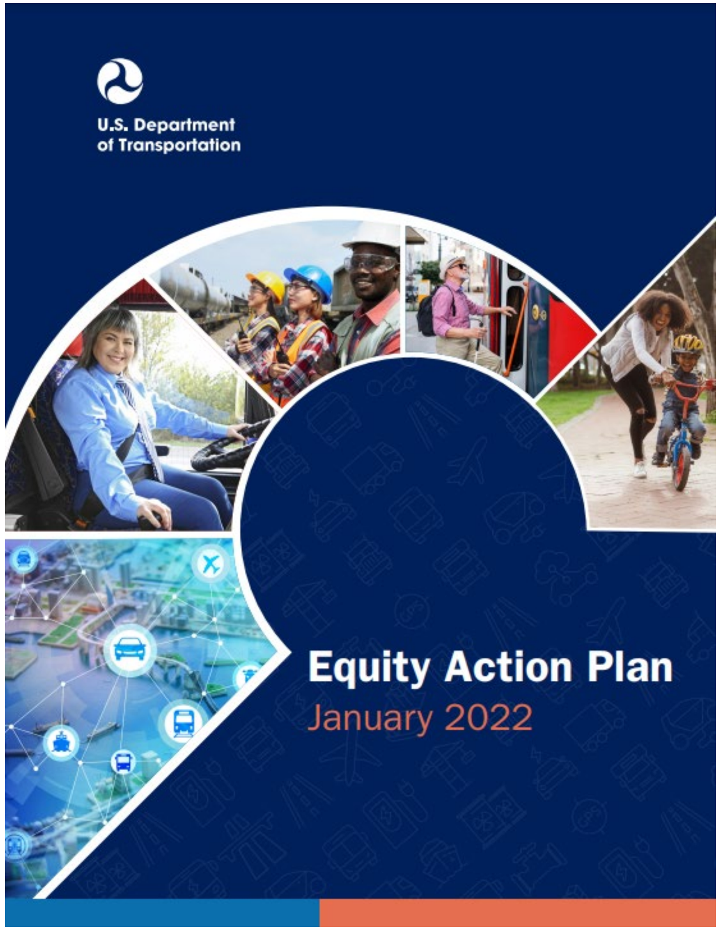
Research, Development and Technology

Equity Measure Research

November 28, 2023

Objectives

- Contribute to Federal and DOT equity efforts:
  - Align with Executive Orders 13985 and 14091 and the DOT Equity Action Plan.
  - Align with DOT Strategic Goals: *Equity, Safety, Organizational Excellence.*
- Propose specific performance tracking metrics for different Office of HAZMAT Safety (OHMS) programs.



Context

- Efficiency versus Equity.
    - Tradeoffs are necessary when setting equity targets and pursing equity goals.
    - The most efficient approach may not be the most equitable.
- Equity is context specific.
    - Different programs can and should measure and track equity differently.
    - Different types of data need to be collected depending on the program area.
- Program areas can apply practical approaches for equity measures.

Methodology

Project Approach

Literature and Data Review → Program Interviews → Proposed Measures

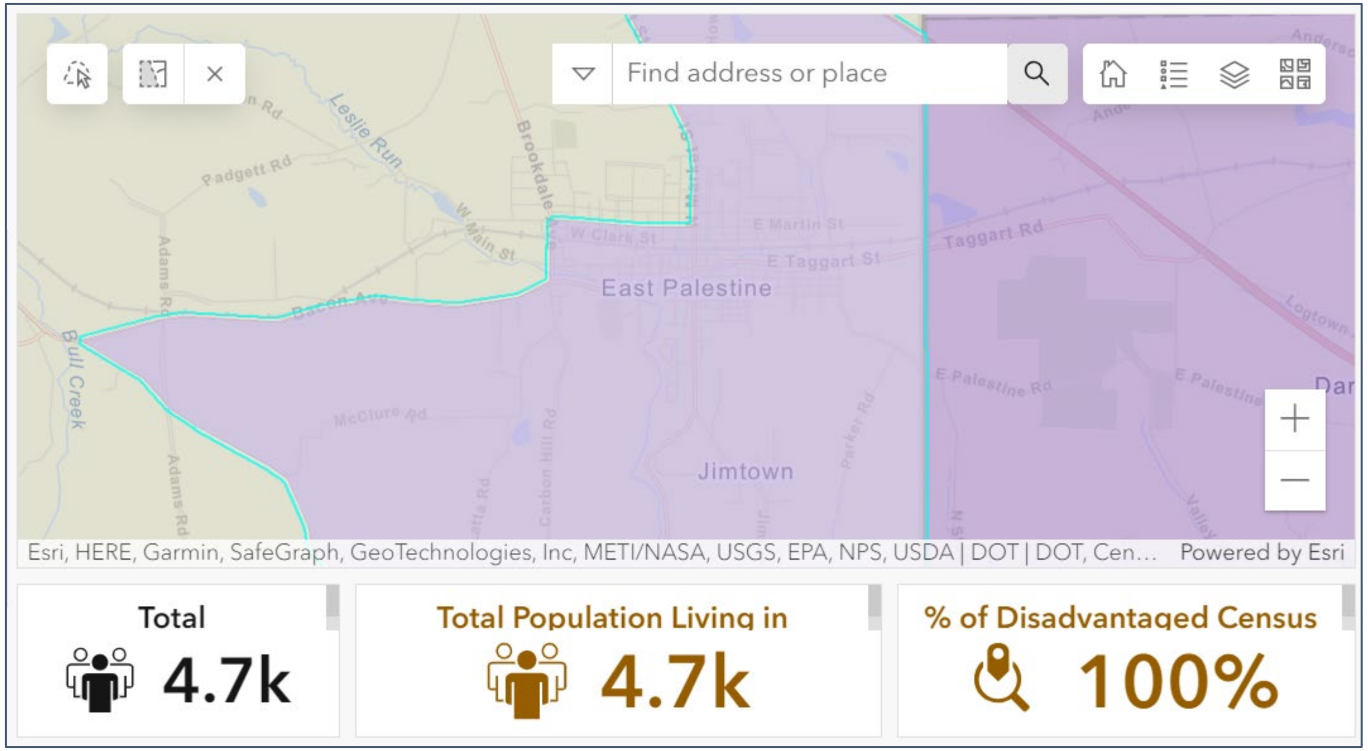
Program Areas Studied

- Investigations and Inspections
- Outreach and Community Liaisons
- Special Permits
- Research, Development, and Technology
- Grants

Defining Vulnerable Communities

Used the USDOT's Equitable Transportation Community (ETC) Explorer to assess the cumulative burden communities experience in five components:

- Transportation Insecurity
- Climate and Disaster Risk Burden
- Environmental Burden
- Health Vulnerability
- Social Vulnerability

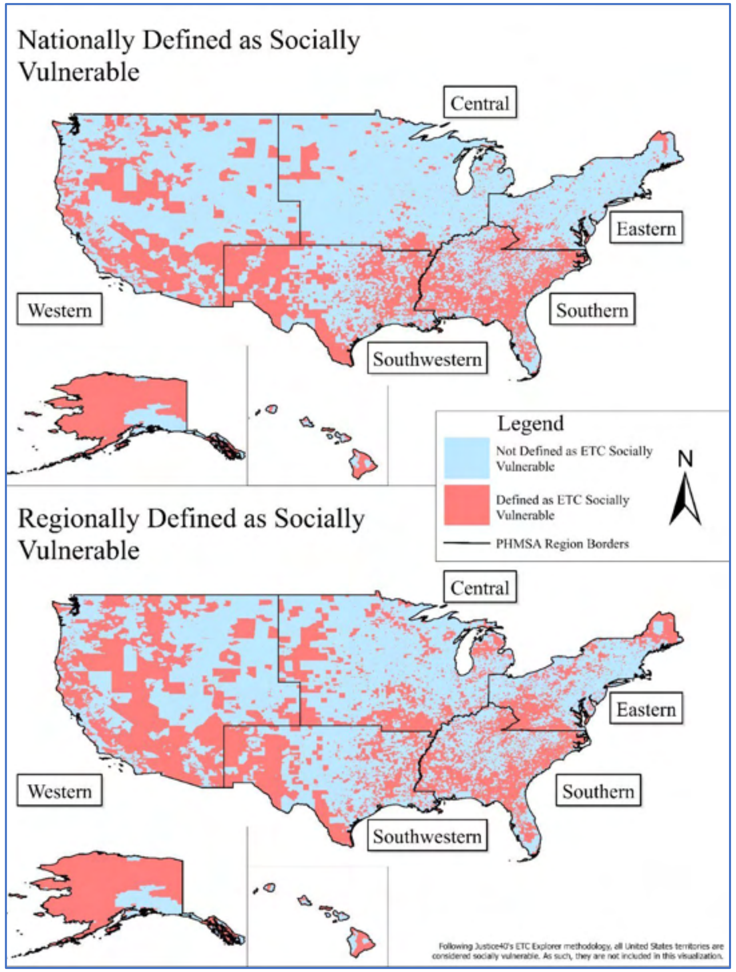


Social Vulnerability Components

Subcomponent	Metric
Socioeconomic Status	Percent of population with Income below 200% of poverty level.
	Percent of people age 25+ with less than a high school diploma.
	Percent of people age 16+ unemployed.
	Percent of total housing units that are renter-occupied.
	Percent of occupied houses that spend 30% or more of their income on housing with less than 75k income.
	Percent of population uninsured.
	Percent of households with no internet subscription.
	Gini Index.
Household Characteristics	Percent of population 65 years or older.
	Percent of population 17 years or younger.
	Percent of population with a disability.
	Percent of population (age 5+) with limited English proficiency.
	Percent of total housing units that are not mobile homes.

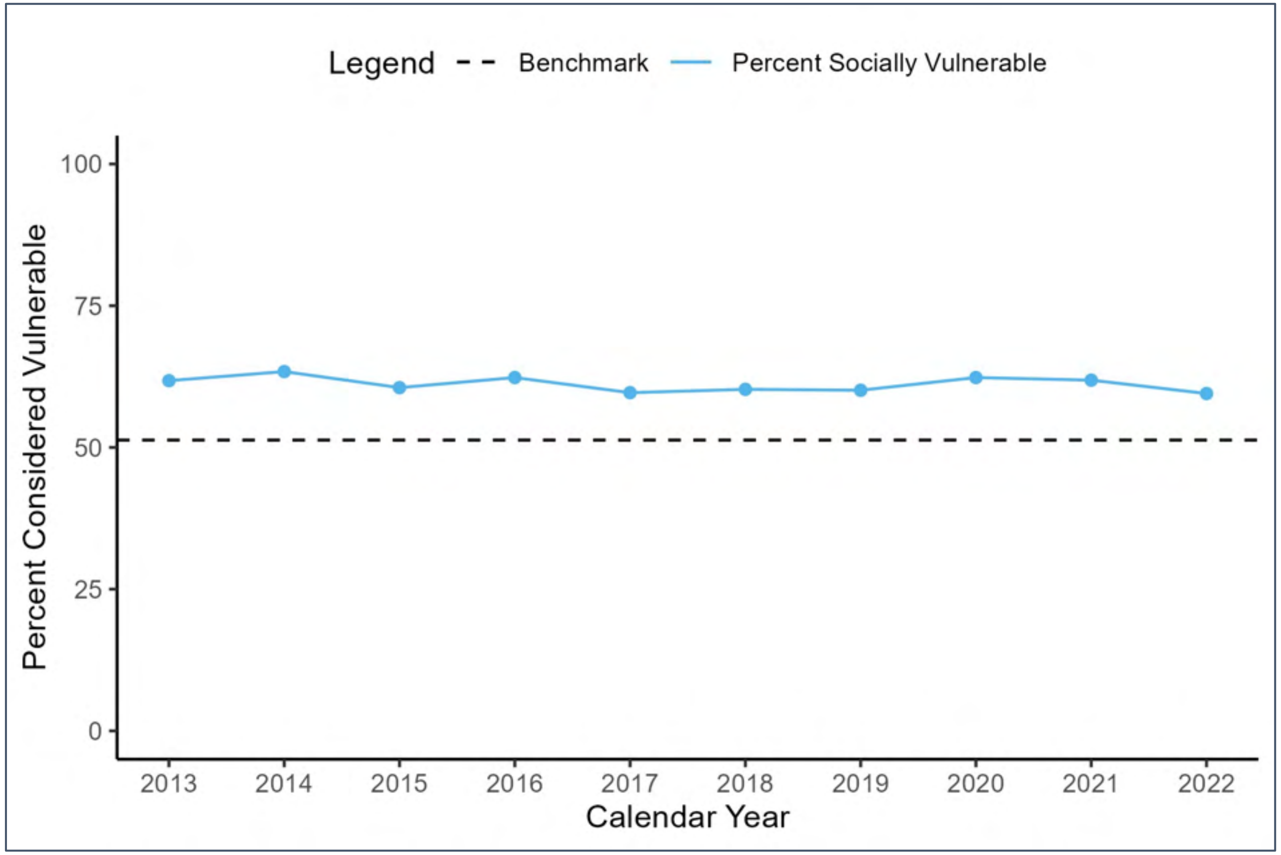
Defining Vulnerable Communities

- The social vulnerability metrics were compiled and converted to scores for US Census Tracts.
- Following ETC methodology, the top 35% of Census Tracts were considered vulnerable.



Results

Investigations and Inspections



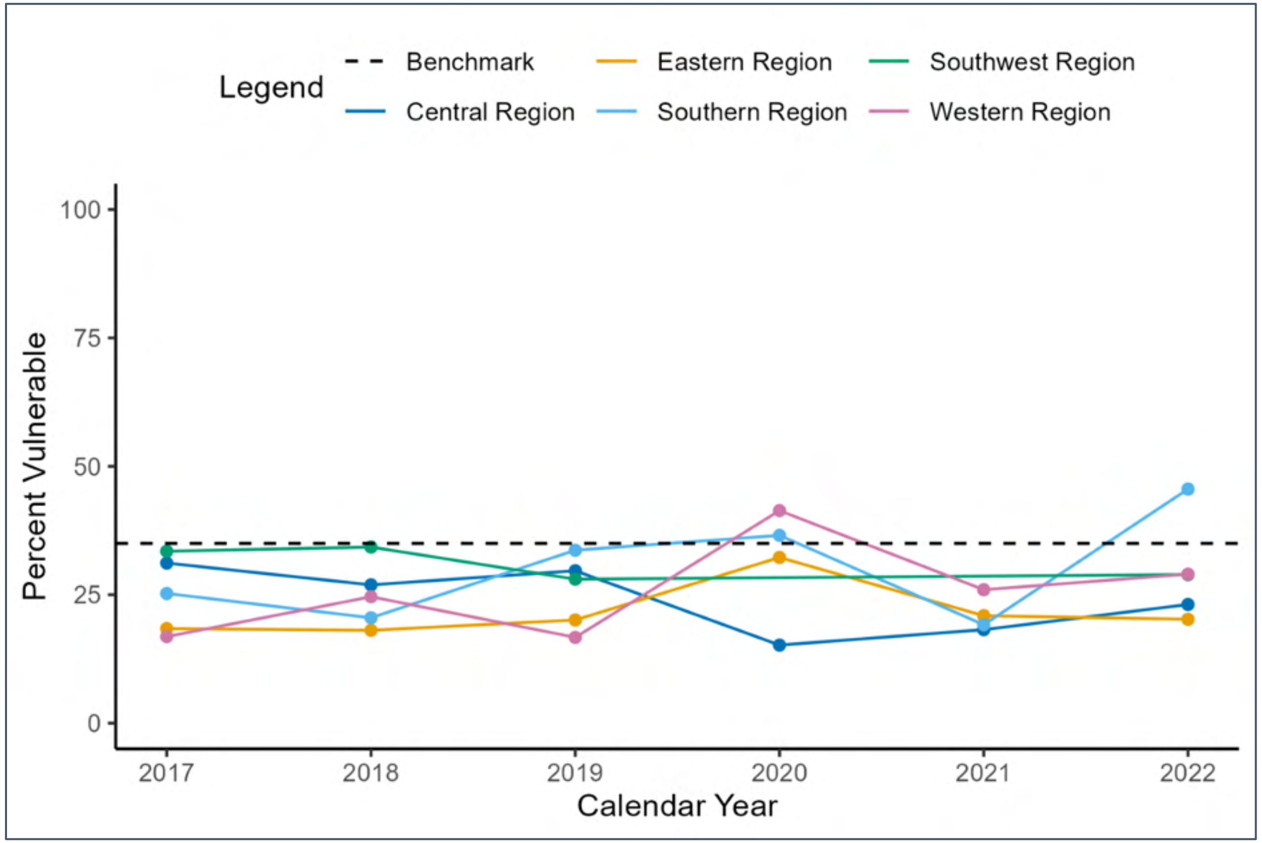
Proposed Measure:

- Percentage of shipper inspections occurring in socially vulnerable areas (compared to the location of all known shippers) nationally and regionally.

Outreach and Community Liaisons (CL)

Proposed Measures:

- Systematically measuring percentage of outreach events serving socially vulnerable areas nationally and regionally.
- Track progress towards Spanish-language translation goals of outreach material.

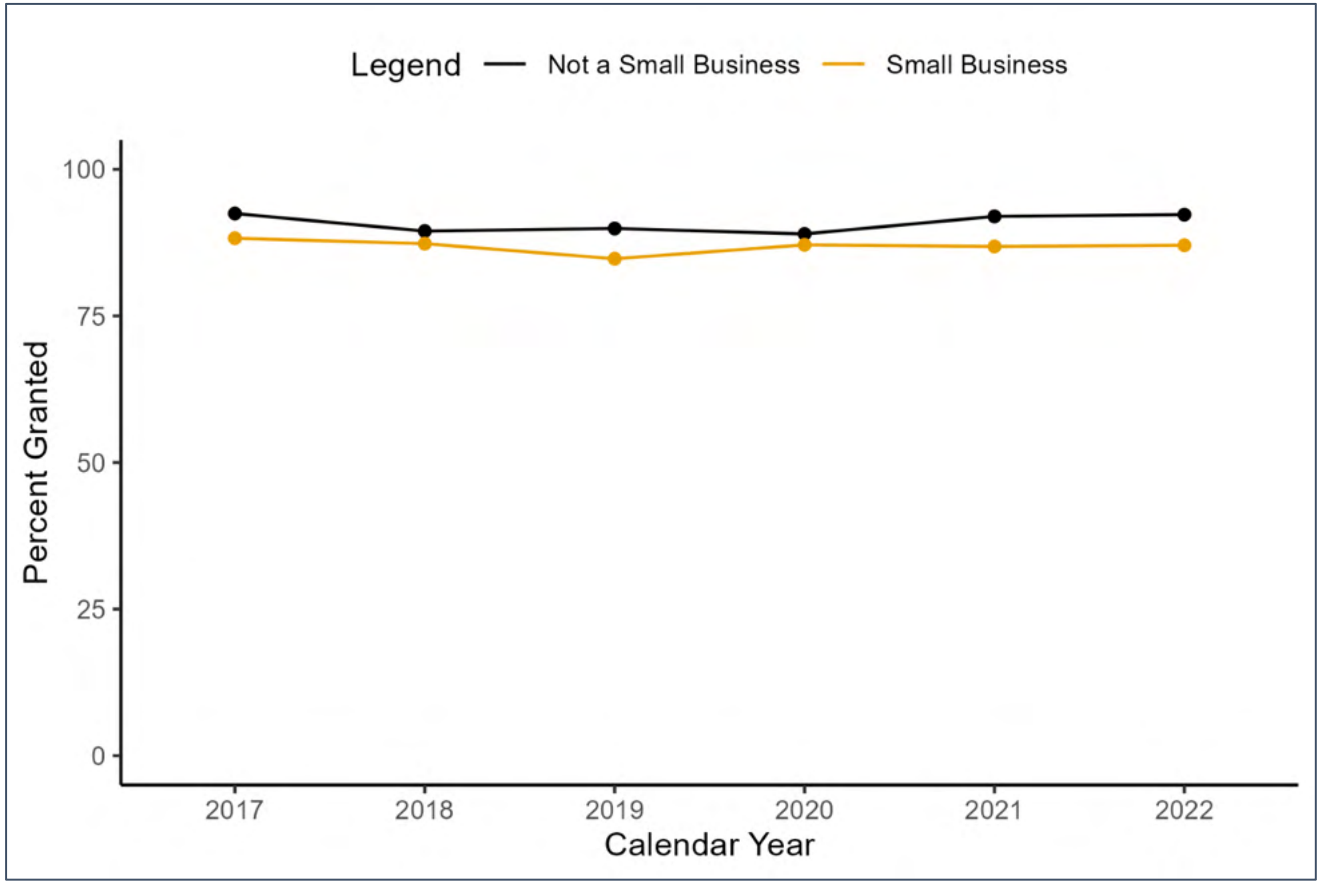


Outreach and Community Liaisons (CL)

Proposed Measures:

- Systematically measuring percentage of outreach events serving socially vulnerable areas nationally and <u>regionally</u>.
- Track progress towards Spanish-language translation goals of outreach material.

Special Permits



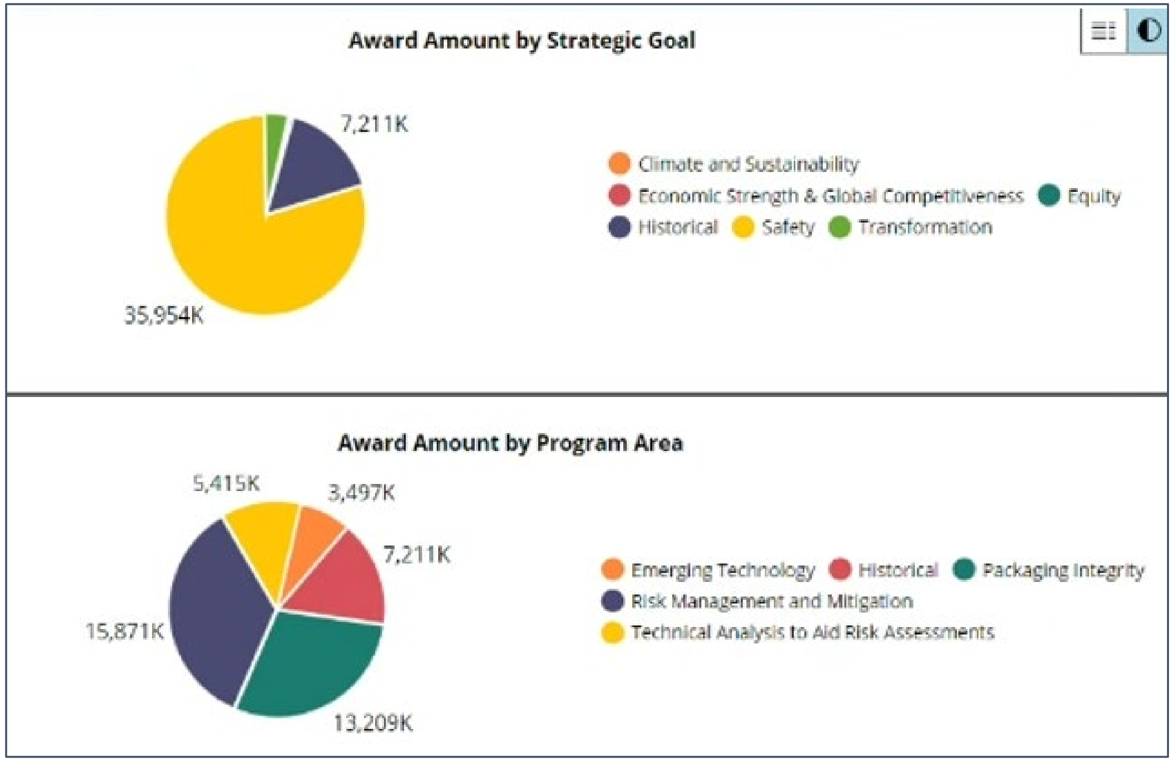
Proposed Measure:

- Percentage of applicants and accepted special permits by equity consideration (i.e., small business, minority-owned, woman-owned, etc.).
- Track equity impacts of special permit conversions.

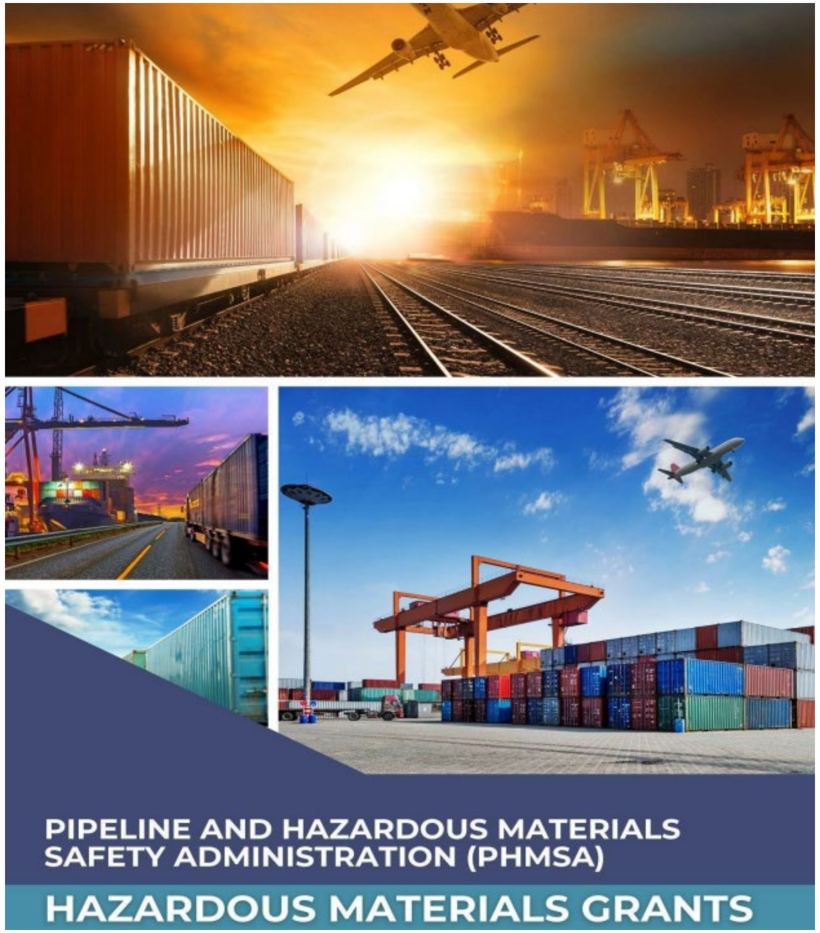
Research, Development, and Technology

Proposed Measures:

- Percentage of research funds that go to small businesses, women-owned businesses, and minority-owned businesses.
- Track equity impacts of specific research efforts and programs.



Grants



Proposed Measures:

- Percentage of funds awarded by grantee and subgrantee type (i.e., state, local, tribal).
- Potential for location-based (urban vs. rural) analysis if more data are collected.

Serious Incident Analysis

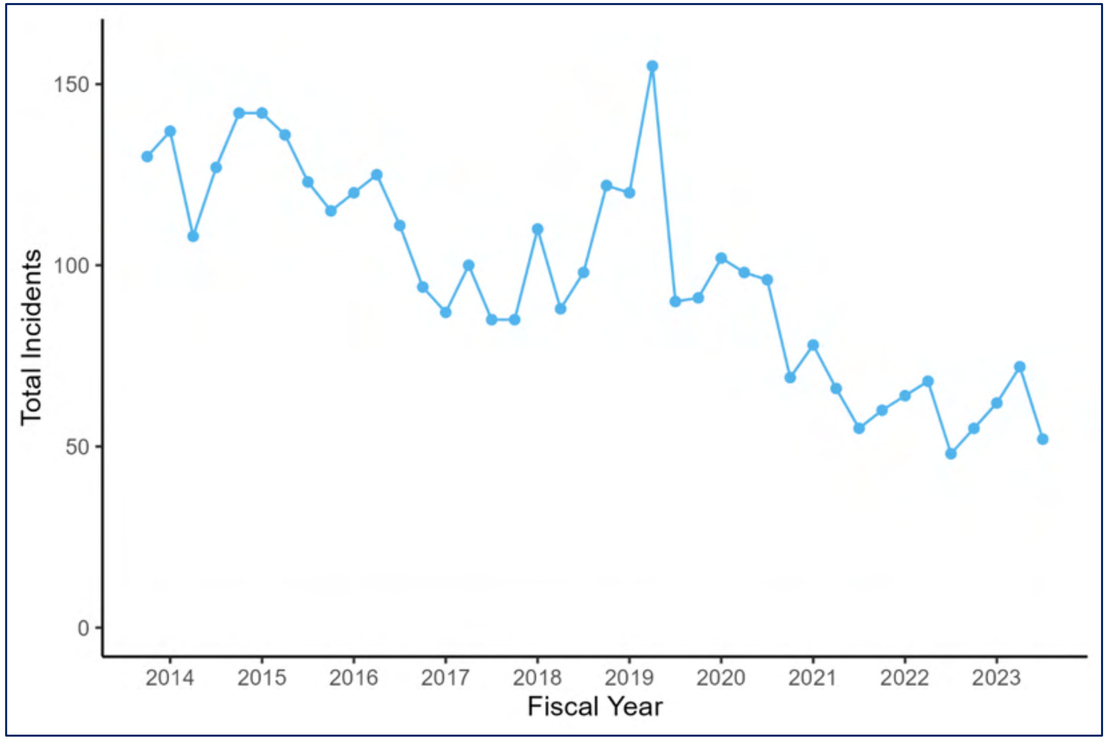
Serious Incident Analysis

- OHMS's defines an incident as *serious* if the incident resulted in one or more of the following items:

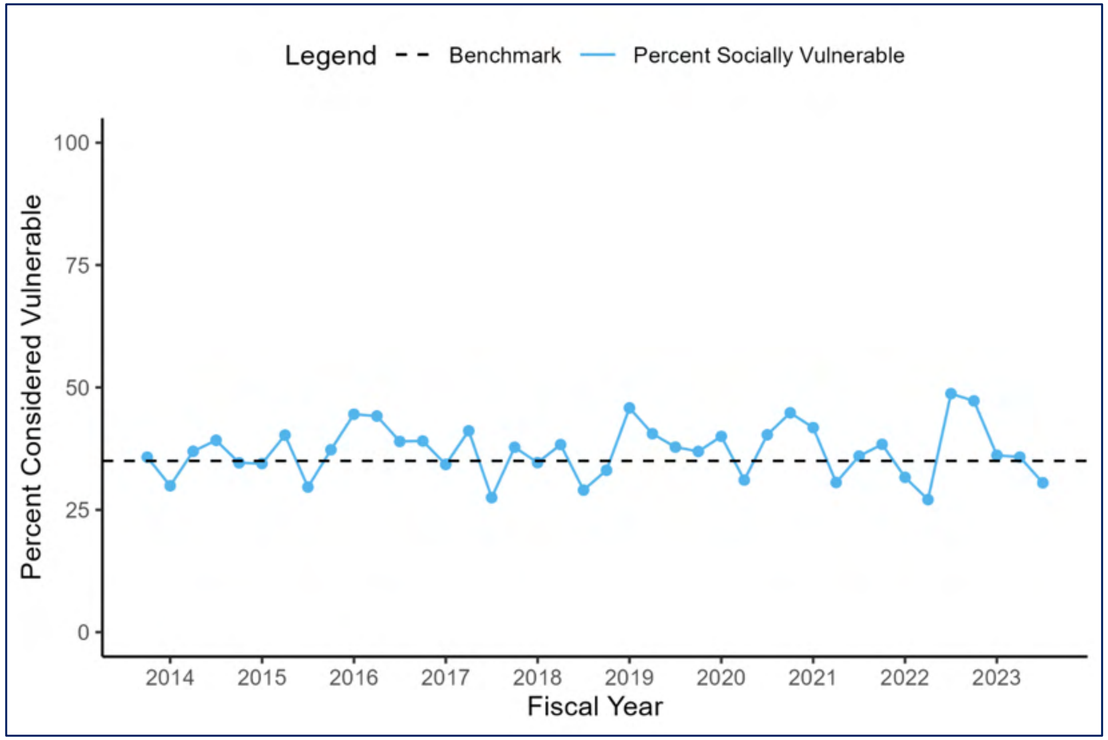
Serious Incident Definition
a fatality or major injury caused by the release of a hazardous material
the evacuation of 25 or more employees or responders or any number of the general public as a result of release of a hazardous material or exposure to fire
a release or exposure to fire which results in the closure of a major transportation artery
the alteration of an aircraft flight plan or operation
the release of radioactive materials from Type B packaging
the suspected release of a Risk Group 3 or 4 infectious substance
the release of over 11.9 gallons or 88.2 pounds of a severe marine pollutant
the release of a bulk quantity (over 119 gallons or 882 pounds) of a hazardous material.

Serious Incident Analysis

Total Serious Incidents



Percent of Serious Incidents in Socially Vulnerable Communities



Key Takeaways

- Equity is context specific.
- OHMS is well positioned to incorporate practical equity measures into their diverse program areas.
  - Existing data can be used to retrospectively track performance from an equity perspective and prospectively inform program area decisions.
  - New data can be collected and incorporated.
- Future work will explore program areas further with case studies and will integrate proposed measures into OHMS performance tracking.

Discussion and Contact Information

- What other factors should be considered?
- Who should we engage with on this topic?

Jonathan Lesko
PHMSA OHMS
Program Analyst
Jonathan.Lesko@dot.gov

Greg Bucci
USDOT Volpe Center
Economist
Gregory.Bucci@dot.gov

Joey Reed
USDOT Volpe Center
Economist
Joseph.Reed1@dot.gov

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

Deactivation of Damaged, Defective, and Recalled (DDR) Batteries

Gordon Waller, **Rachel Carter**, Corey Love | U.S. Naval Research Laboratory

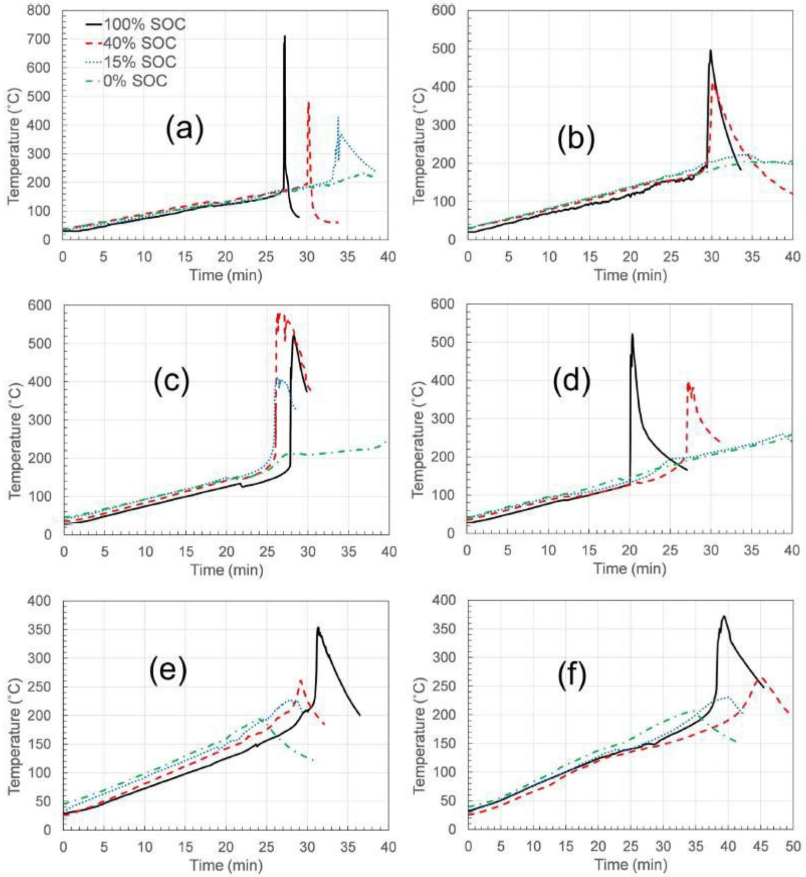
November 28, 2023

U.S. NAVAL RESEARCH LABORATORY

Batteries contain energy even at the end of life!

- Electrochemical energy (state-of-charge > 0%).
- Stranded energy (inaccessible Li deposits in a lithium-ion battery, cells/batteries with safety fuses activated).
- Chemical energy (flammable electrolytes, reactive compounds).

<u>**Project Goal:**</u> Develop a simple, cost effective, and broadly applicable methods to de-energize end of life batteries.



“Safety of Lithium-ion Cells and Batteries with Varying States-of-Charge”. Joshi, T, et al. 14, 2020, Journal of the Electrochemical Society, Vol. 167.

- Researchers at Underwriters Laboratories (UL) reported on effect of SOC on LIB failure during external heating
- Some cell types (Cell A; NCA 18650 and Cell C; NCM 26650) showed thermal runaway at 15% SOC, but none at 0% SOC
- SOC has a strong influence on maximum temperature during thermal runaway and a weaker influence on onset temperature of thermal runaway for all chemistries

<u>Deactivation Target:</u> 0 V

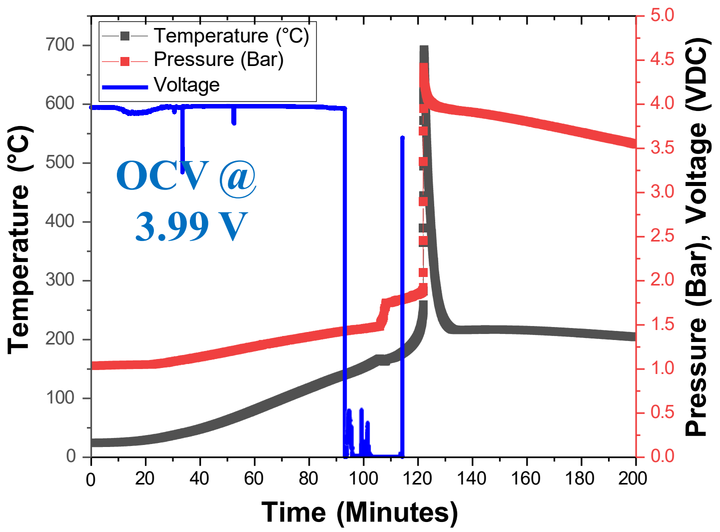
Method	Flexibility	Deployability	Affordability	Safety	Limitations
Saltwater Immersion	High	High	High	Moderate	Corrosion, generation of H_2
Electrical Discharge	Moderate	Moderate	Low to Moderate	High	Many require dynamic load bank / manual interaction with energized terminals
Shredding	Moderate	Low	Low	Low To Moderate	Requires preceding deactivation step or inert / cryogenic conditions

Literature survey of existing deactivation methods suggested saltwater immersion was a reasonable "one size fits all" option, with corrosion being a major barrier to efficacy.

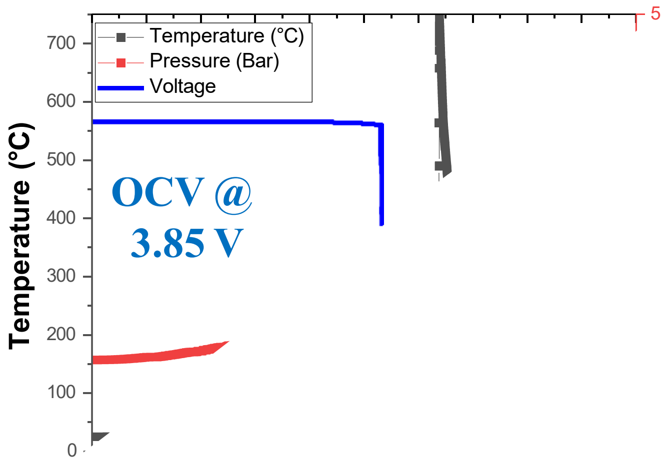
"Deactivation of End-of-Life Batteries", G.H. Waller, R. Carter, C.T. Love, NRL/6170/MR—2023/3 (2023), Accessible on DTIC

Voltage, Temperature, and Pressure for cells submerged 24 hours in saltwater solutions.

3.5 wt% NaCl



5.8 wt% NH_3HCO_3



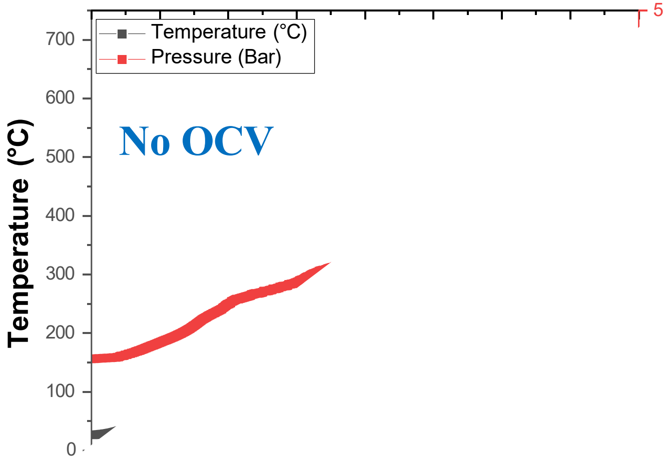
11 wt% $NH_4H_2PO_4$

OCV @ 3.66 V

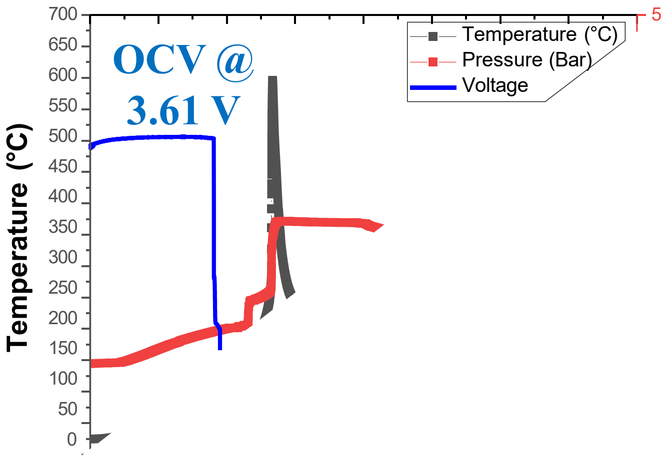
All cells immersed in salt water for 24 hours have OCV equivalent to ≥50% SOC and undergo thermal runaway with external heating.

Voltage, Temperature, and Pressure for cells submerged 72 hours in saltwater solutions.

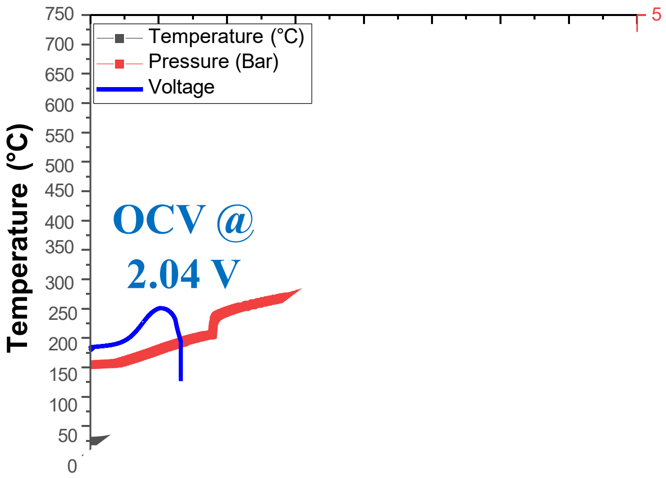
3.5 wt% NaCl



5.8 wt% NH_3HCO_3

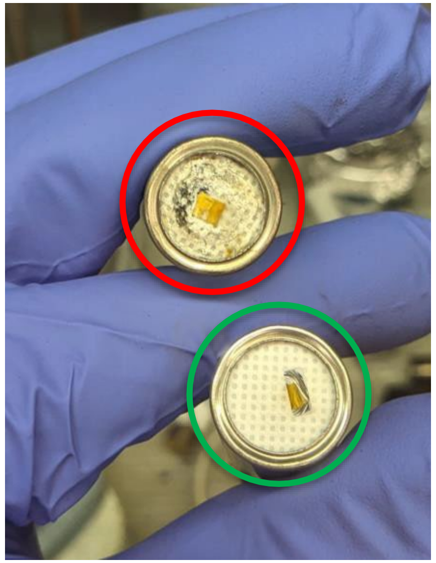


11 wt% $NH_4H_2PO_4$



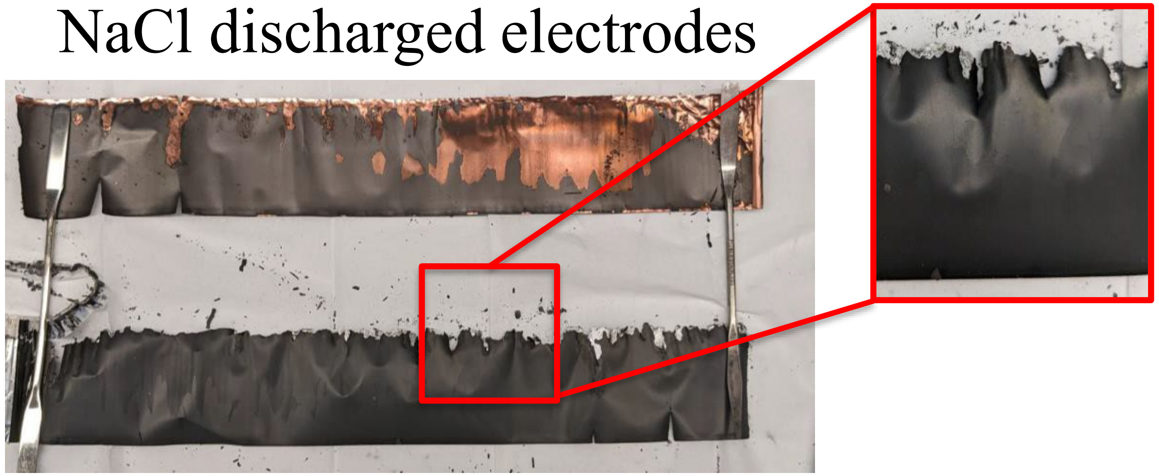
Only cell in 5.8 wt% NH_3HCO_3 undergoes thermal runaway with external heating. Cells in 3.5 wt% NaCl and 11 wt% $NH_4H_2PO_4$ have OCV <0% SOC.

Positive tab connected to cell header in electrically discharged cell.

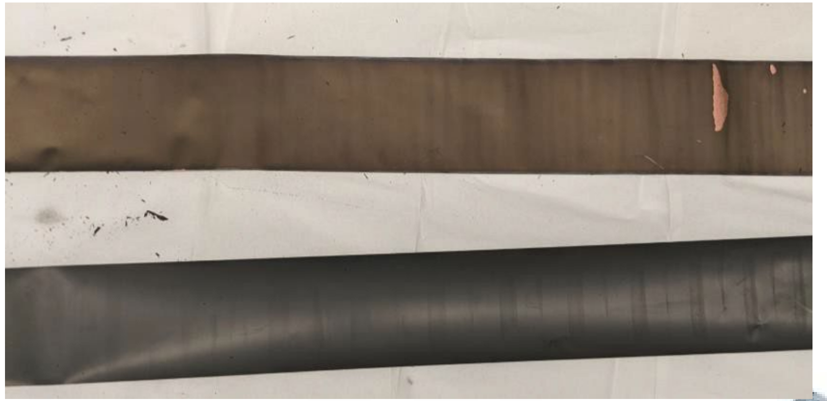


Top of jellyroll in **NaCl discharged** and **electrically discharged** cells shows only NaCl cells have been breached.

NaCl discharged electrodes



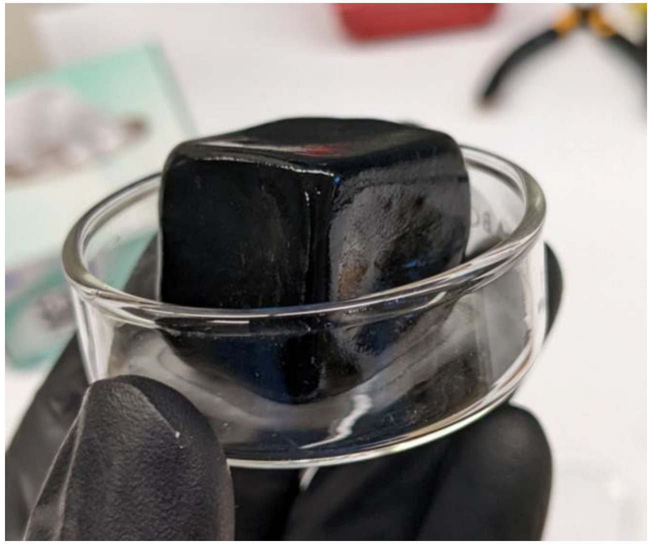
Electrically discharged electrodes

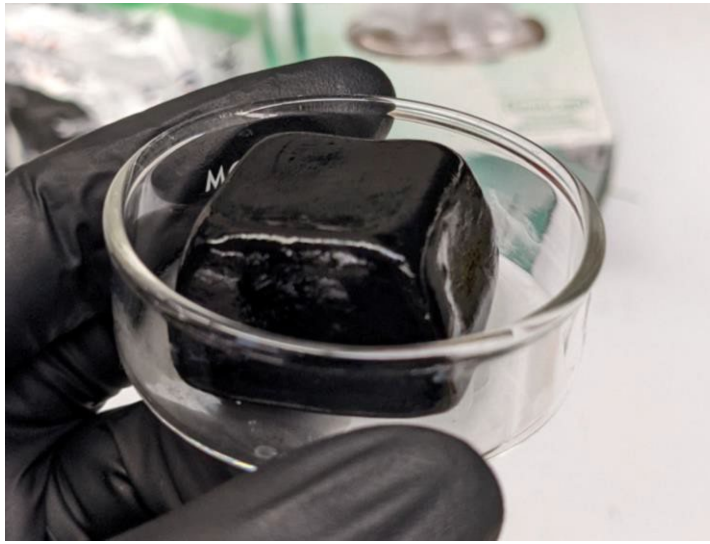


NaCl discharged header

Method	Flexibility	Deployability	Affordability	Safety	Limitations
Saltwater Immersion	[illegible]	[illegible]	High	[illegible]	[illegible] generation of H_2
Electrical Discharge	Moderate	Moderate	Low to Moderate	High	Many require dynamic load bank / manual interaction with energized terminals
Shredding	[illegible]	[illegible]	[illegible]	[illegible] To Moderate	[illegible]

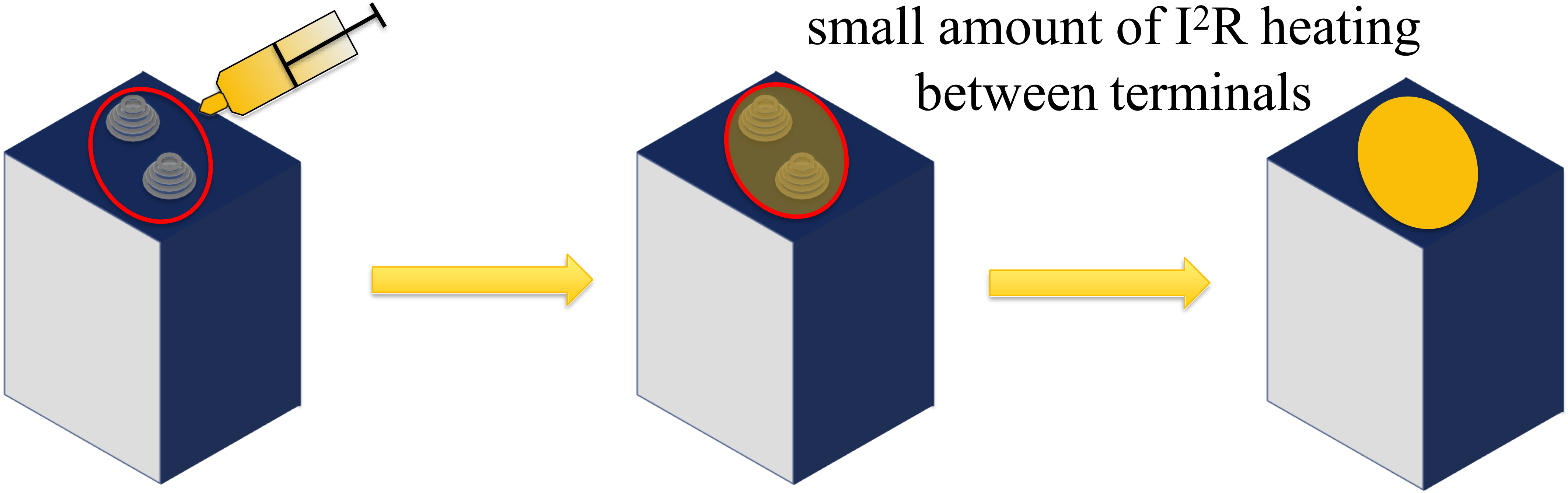
- Electrical discharge (external short circuit) avoids hydrogen generation and corrosion, however existing methods are not ideal.
- Can we improve on the limitations of the external short circuit method?





Concept Electrically conductive water-based gel

- Water soluble polymer is used to encapsulate conductive carbon. Gel flows onto / into battery cavities to create an electrical discharge pathway. Conductivity increases as water evaporates.
- Polymer utilized is non-toxic and low cost – no recovery of gel is required.



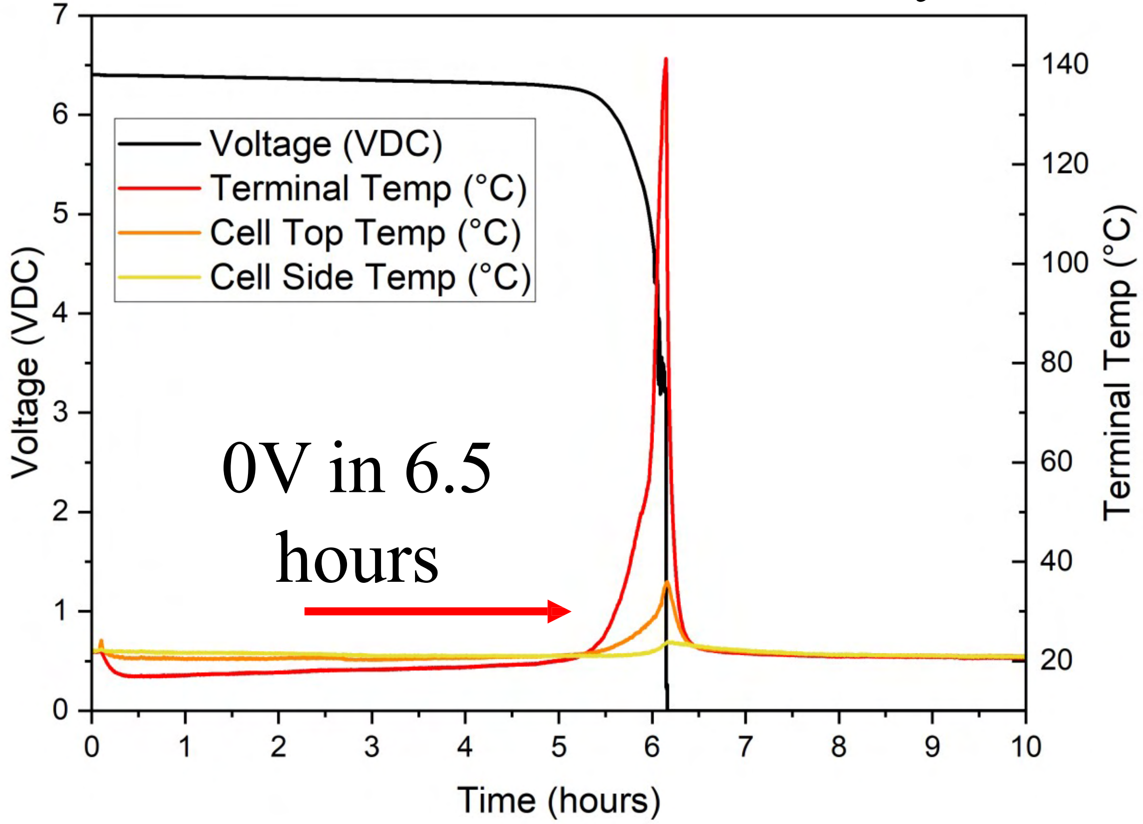
Discharge proceeds with small amount of I^2R heating between terminals

Gel applied via extrusion from syringe / caulk gun

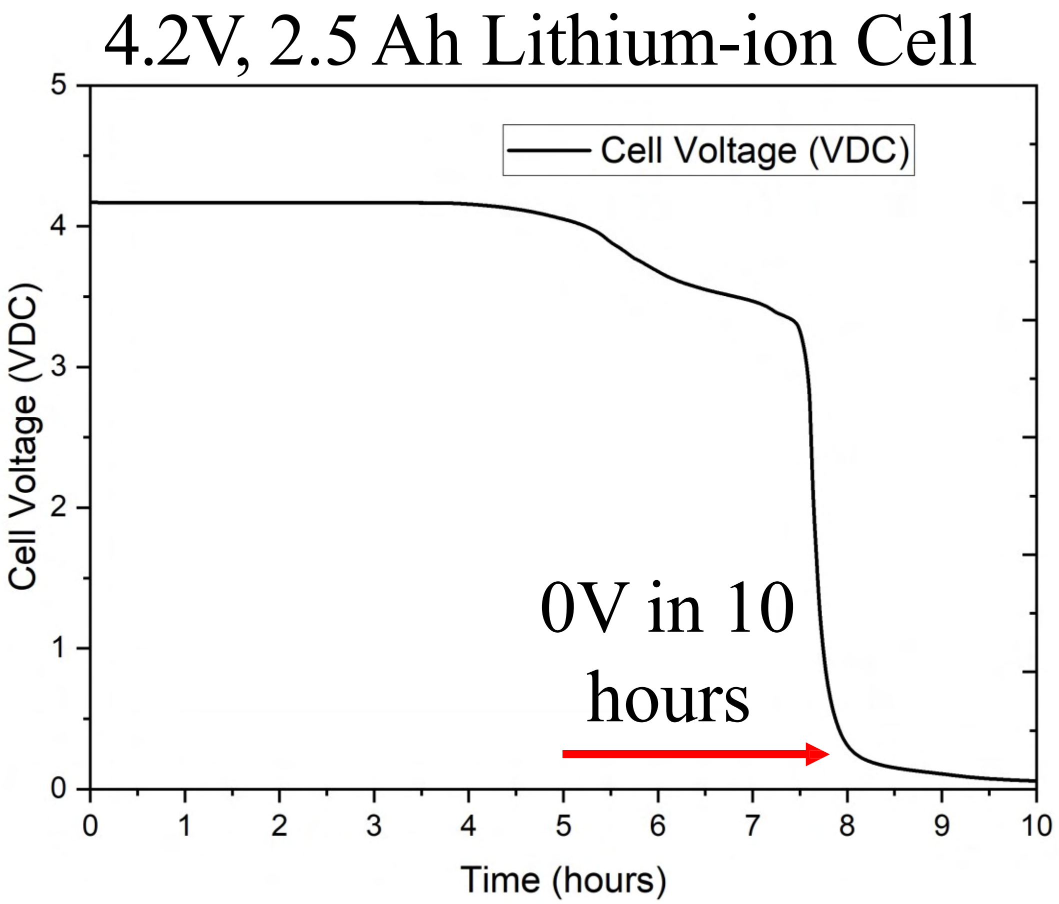
Gel dries over a few hours, conductivity increases

Cell is completely discharged within 24 hours

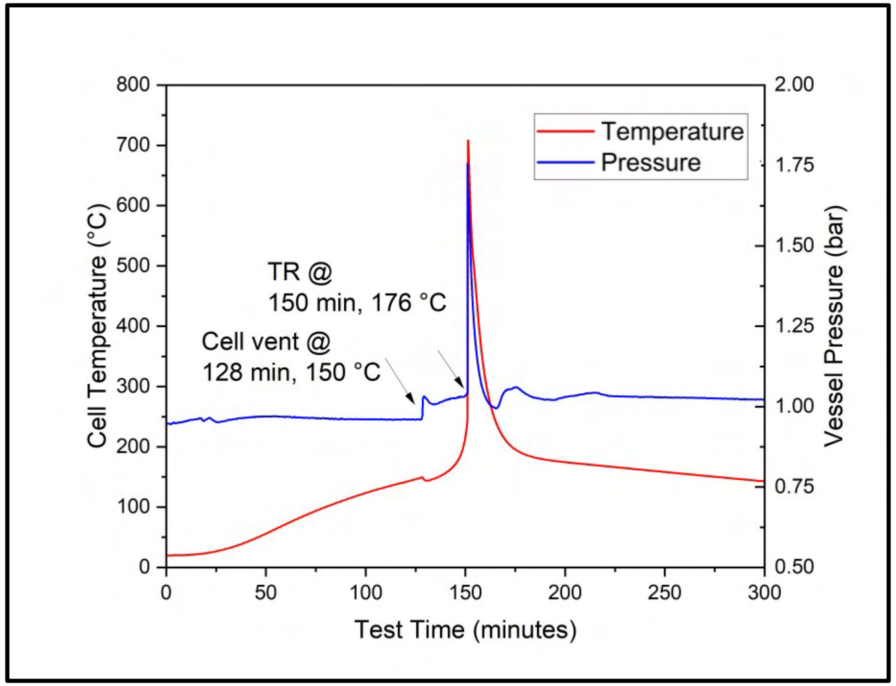
20 Ah, 6V Alkaline battery



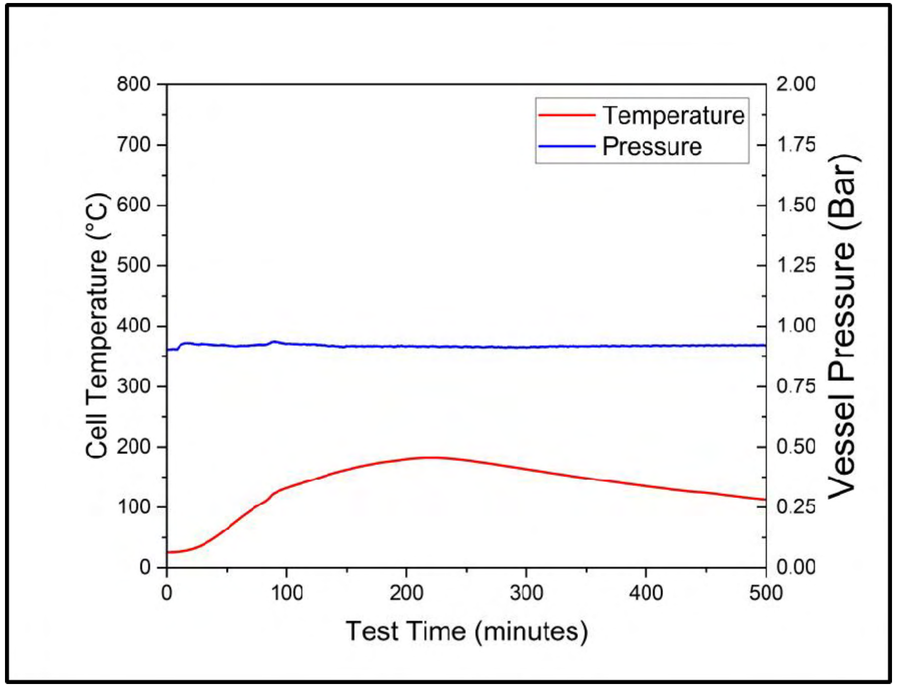
Gel applied across header with shrink wrap removed.



3.5V / 22% SOC LIB

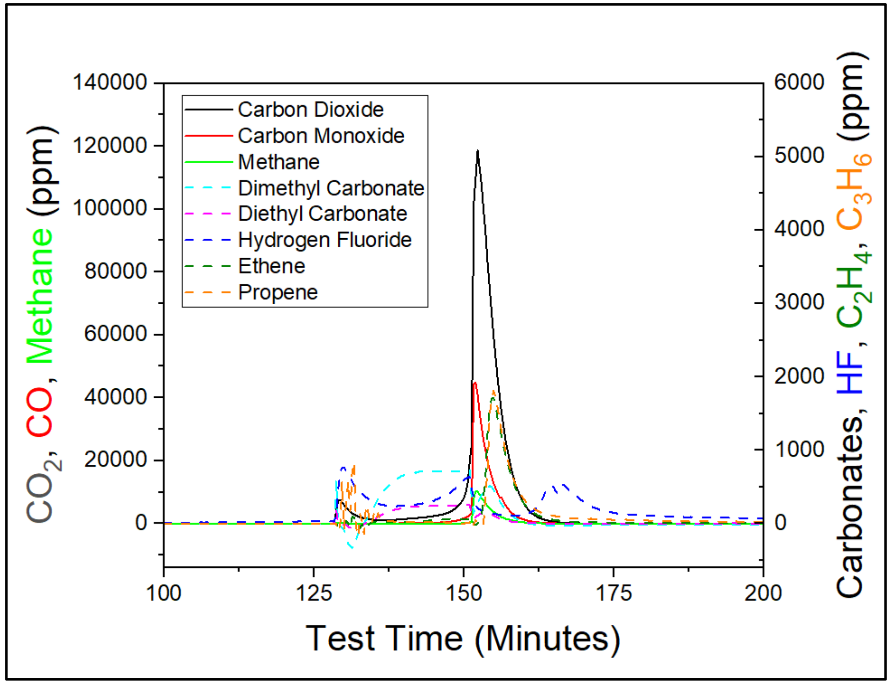


0V / 0% SOC LIB

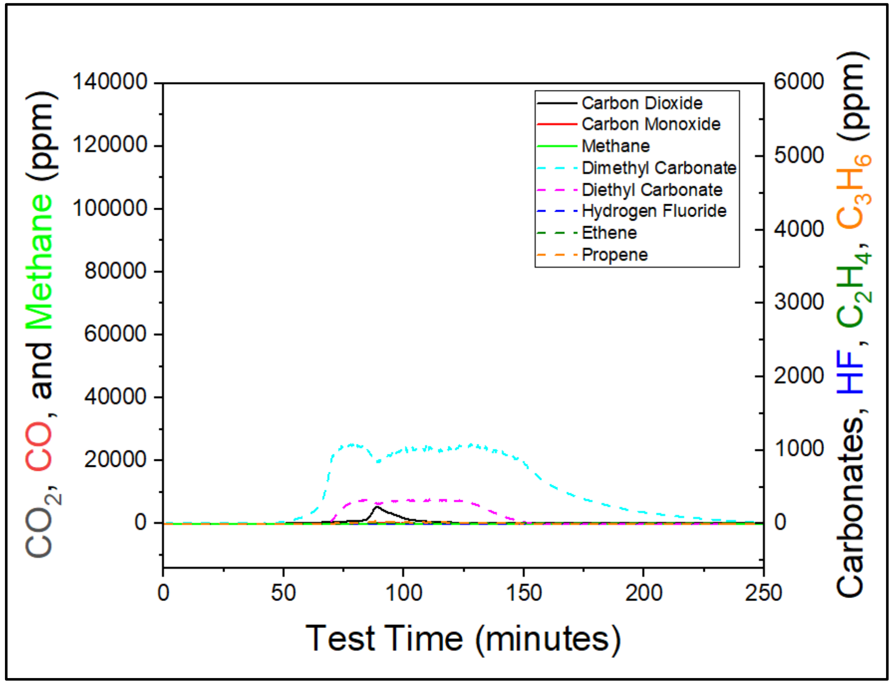


18650 LIB Cells discharged to 0V by electrically conductive gel show no signs of thermal runaway when heated to 180 °C.

3.5V / 22% SOC LIB



0V / 0% SOC LIB



18650 LIB Cells discharge to 0V by electrically conductive gel show have significantly lower concentrations of every measured gas species.

- Deactivation using electrically conductive gel was demonstrated on multiple cell formats / chemistry and results in a complete elimination of thermal runaway behavior and a significant decrease in gas concentrations with external heating

- Future work is focused on improving gel application method and demonstrations using more relevant battery packs.

Contact Information

Technical Point of Contact:

Gordon Waller, Ph.D.

gordon.waller@nrl.navy.mil

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

Sodium-ion Battery Testing

Rachel Carter, Gordon Waller, Corey Love | U.S. Naval Research Laboratory

U.S. NAVAL RESEARCH LABORATORY

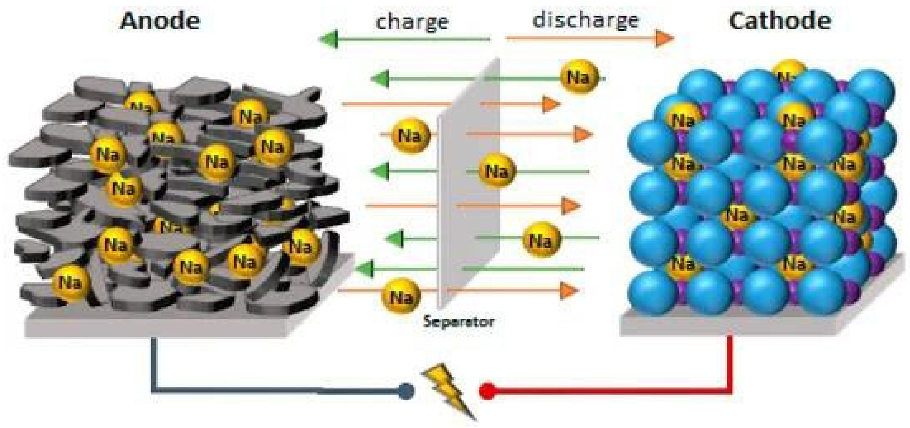
November 28, 2023

Problem Statement:

Sodium-ion Batteries are quickly entering the global market. Companies suggest higher safety.

Overall Goal:

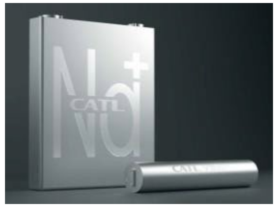
Preliminary safety and performance validation for safe transport



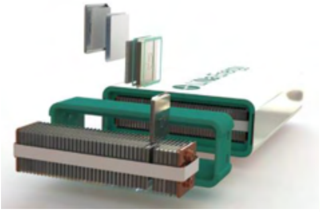
Batteries **2019**, *5*(1), 10

- Capable of 0 V Storage
- Fast Charging
- Aqueous and non-aqueous electrolytes
- Wide range of anode and cathode materials



Company (Origin)	Nominal Voltage (V)	Nominal Energy Density (Wh/kg)	Cathode Material	Unit Cell Size (g); Form factor	Other Notes
Covered for Distro A	**3.6**	**262**	**NCA; $LiNi_xCo_yAl_zO_2$**	**46 18650**	**High energy**
	3.3	***113***	***LFP $LiFePO_4$***	***76 26650***	***High safety; high power***
	1.8	**22**	**Prussian Blue Na2Fe[Fe(CN)6]**	**305 Pouch**	**High safety/low energy; aqueous;**
	1.8	***25***	***Prussian Blue Na2Fe[Fe(CN)6]***	***800 pouch***	***New pouch with 130 A nominal charge current***
	3.6	**80**	**NVP Phosphate $Na_3VO_x(PO_4)_2F_y$**	**33 18650**	**High safety; high power;**
	3.1	***140***	***Layered metal oxide $NaNi_{1-x-y-z}M^1_xM^2_yM^3_zO^2$***	***660 Pouch***	***competitive with LFP; planned in FY23***
	3.0	***128***	***Na(NixFeyMnz)O2***	***40 18650***	***Arriving any day***
	3.2	160	Prussian White (R-Na1.92Fe[Fe(CN)6])	Prismatic and Large Cylindrical	FAR Regulated
	3.2	145	Prussian White	Pouch, 26650, 32138	FAR Regulated
	3.2	~100	Prussian White (R-Na1.92Fe[Fe(CN)6])	cylindrical	Recently began selling product
	2.6	~100	High temperature chemistry (SS) $NiCl_2$	Pouch	No product yet; Solid state

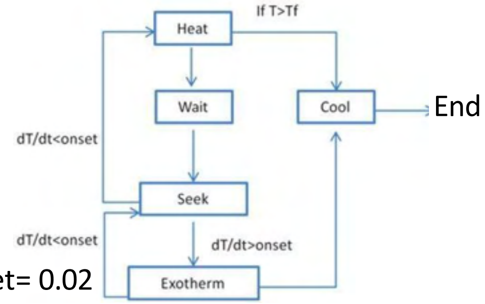



Tested in 22-23 ***Will be tested in 24***

Failure-Mode Testing

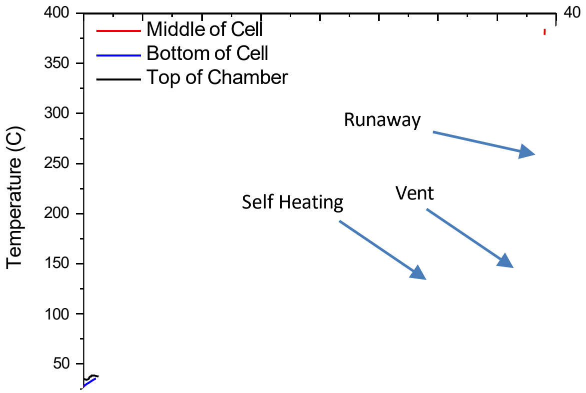
1. Accelerating Rate Calorimetry- thermal stability and chemical reactivity

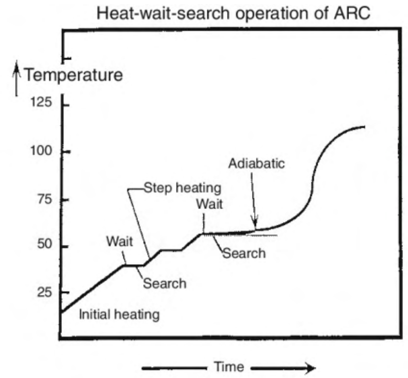
T_f= 300°C

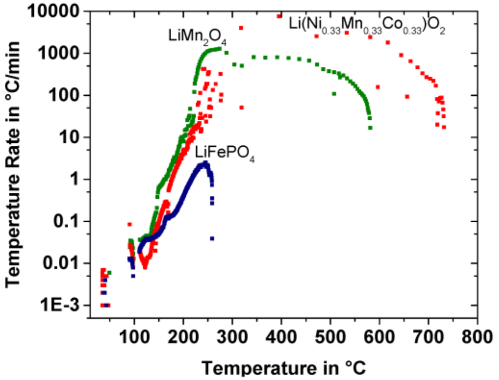


Onset= 0.02 °C/min

Batteries **2017**, *3*(2), 14

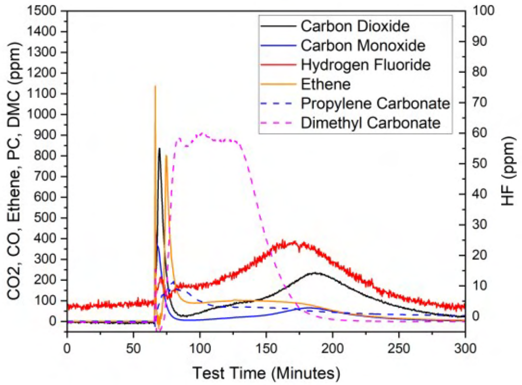






Klein, Carter, Love et al. J. Vis. Exp. (175), e60342, doi:10.3791/60342 (2021)

3. Nail Penetration- mechanical abuse stability

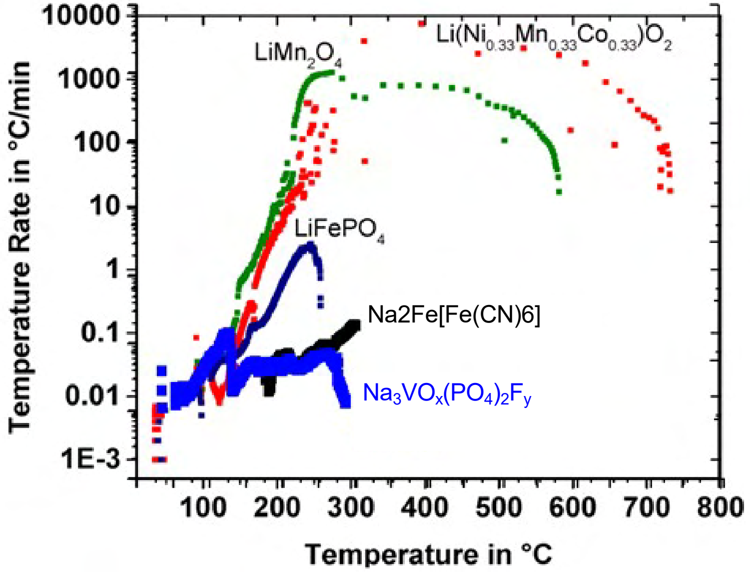


2. Gas Analysis- Toxicity of off gases

Company Name	Cathode Type	Spec ED Confirmation- color indicates agreeance	Accelerating Rate Calorimetry – color indicates severity	Gas Analysis- color indicates toxicity	Nail Penetration- color indicates severity
Covered for Distro A	NCA; $LiNi_xCo_yAl_zO_2$	Complete FY23	Complete FY23	Complete FY23	Complete FY23
	LFP $LiFePO_4$	Cells in hand			
	Prussian Blue Na2Fe[Fe(CN)6]	Complete FY22	Complete FY22	**Waiting on replacement parts**	**Waiting on replacement parts**
	Prussian Blue Na2Fe[Fe(CN)6]	Cells procured			
	NVP Phosphate $Na_3VO_x(PO_4)_2F_y$	Complete FY 22	Complete FY22	Complete FY23	Complete FY23
	$NaNi_{1-x-y-z}M^1_x M^2_y M^3_z O_2$	**Cells quoted but not ready to ship**			
	Na(NixFeyMnz)O2	Cells shipped			

On time
Waiting
Delayed

Safer
Some Risk
Dangerous



Cell Type	LIB (NMC)	LIB (LFP)	SIB (VPF)	SIB (FeCN)
Capacity (Ah)	3	1.1	0.7	4.5
Specific heat, c_p (J/gK)	0.9	0.95	1.05	2
Mass (g)	45	39	33	305
Onset temp (°C)	125	140	55	170
Max T rise (°C/min)	5000	100	0.1	0.18
Temp at Max Rise (°C)	400	220	120	300
Max Heat flux (W)	3375	62	0.06	0.94
Enthalpy (kJ)	20	7	7.8	100
Heat of reaction (J/g)	600	200	235	250
Data Source	Batteries 2017, 3 (2), 14	Batteries 2017, 3 (2), 14	this work	this work

Gas Analysis Testing

Cell Type	SOC	Capacity (Ah)	Voltage (VDC)	Mass (g)	Wh/kg
Li-ion 18650	22%	0.75	3.59	45.8	59
Na-ion 18560	100%	0.7	4.25	33	77

- Li-ion 18650 at shipping SOC and Na-ion 18650 at 100% SOC were heated at 1-2 °C per minute inside of a pressure vessel.
- Vessel was purged with nitrogen for 30 minutes prior to heating and purged continuously during testing.
- All exhausted gases (N_2 + gases produced by battery failure) were flowed through an FTIR gas cell.

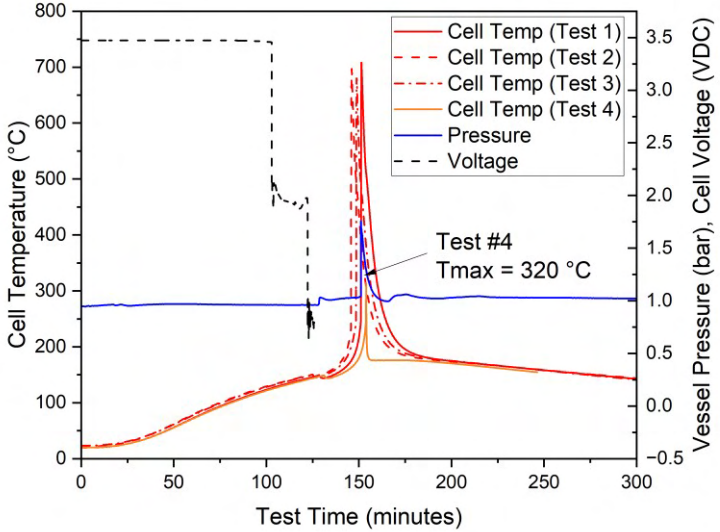
Exhaust

Heated sample line

Nitrogen

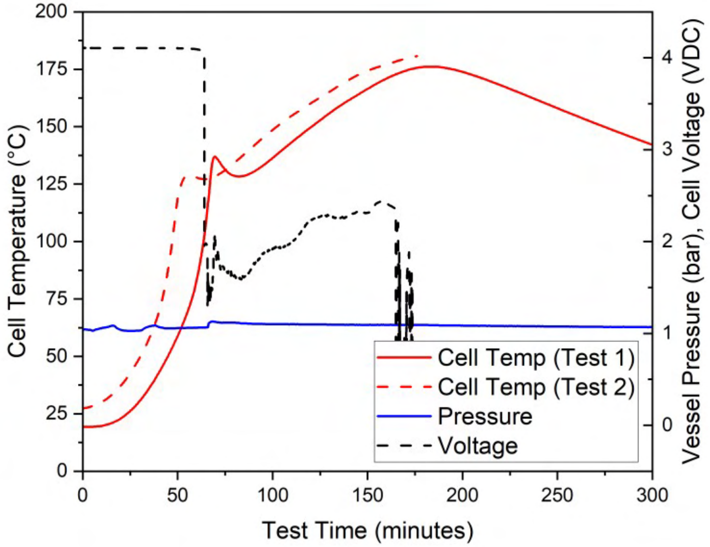
- Pressure Vessel (PV) contains all gas produced during LIB testing. Limited to small cells but contains all evolved gas.
- Fluoropolymer heated sample line at 180 °C minimizes condensation of evolved gases and reactions with acid gases (e.g. HF).
- FTIR uses 2M gas cell to measure many species of interest in the ppm to % range

Li-ion 22% SOC

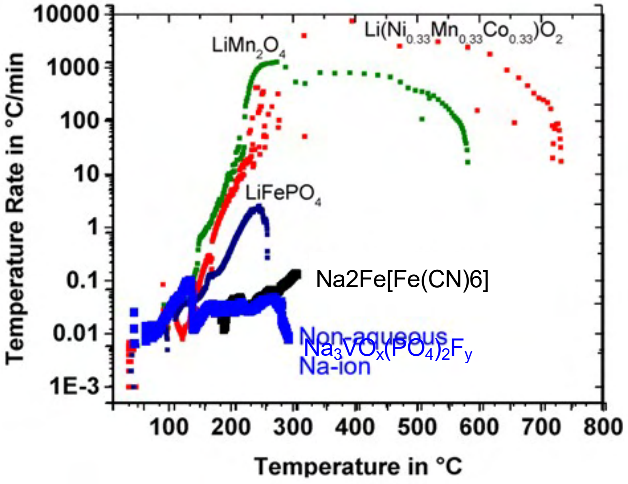


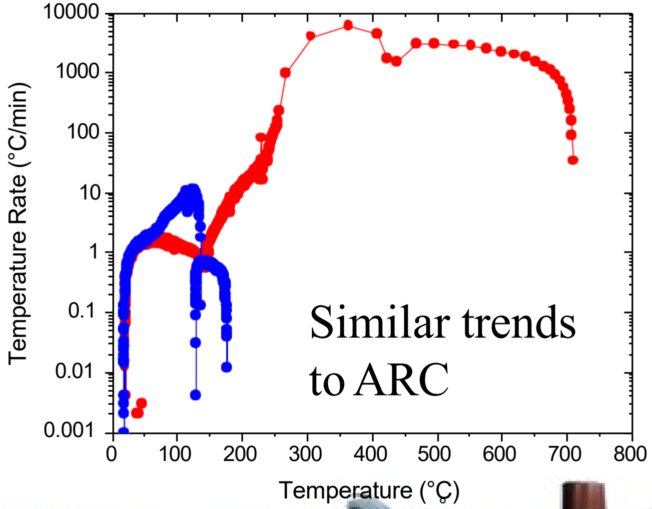
Voltage drop occurs at 102 minutes / 129 °C before onset of self-heating. Self heating exceeds 5 °C/min at 179 °C and 3 of 4 cells reach a maximum temperature of ~700 °C, Test 4 material ejected

Na-ion 100% SOC



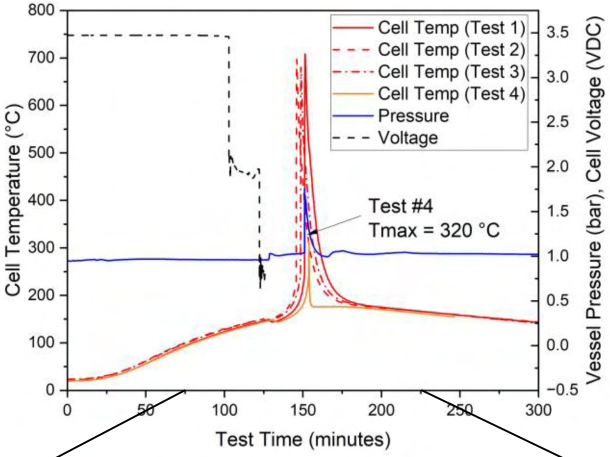
Voltage drop occurs at 64 minutes / 100 °C when self-heating exceeds 5 °C/min. Cell temp reaches a maximum of ~136 °C due to self-heating at 70 minutes, then continues to heat with chamber.

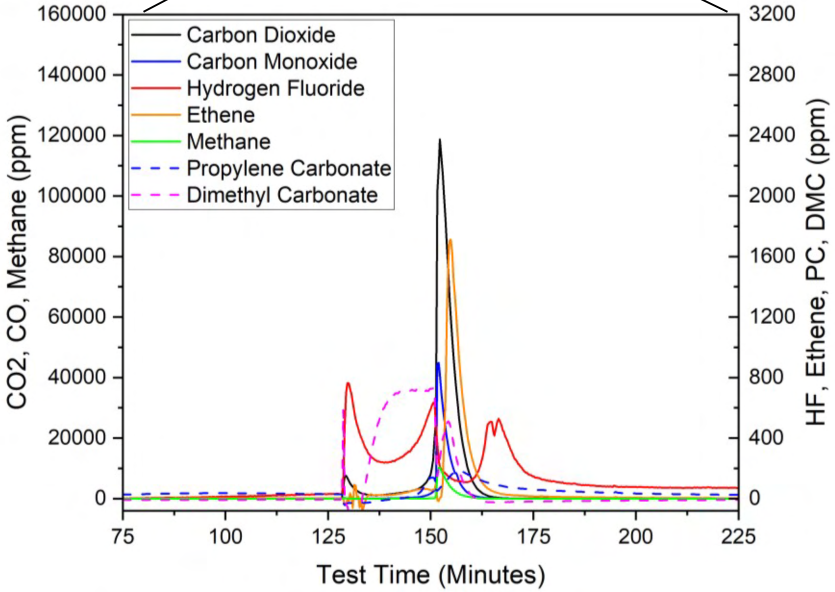




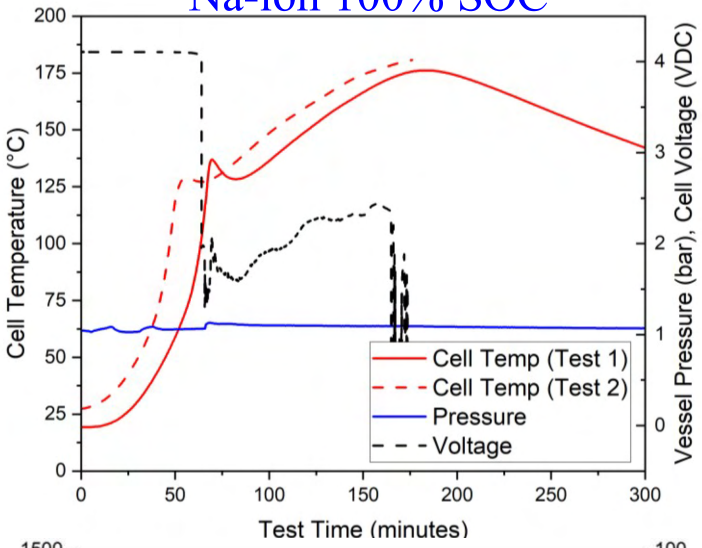
- Initial spike of gas observed at 128 minutes / 150 °C during venting
- Most species reach maximum values during TR at 151 minutes ~700 °C
- Increase in DMC solvent vapor observed between venting and TR

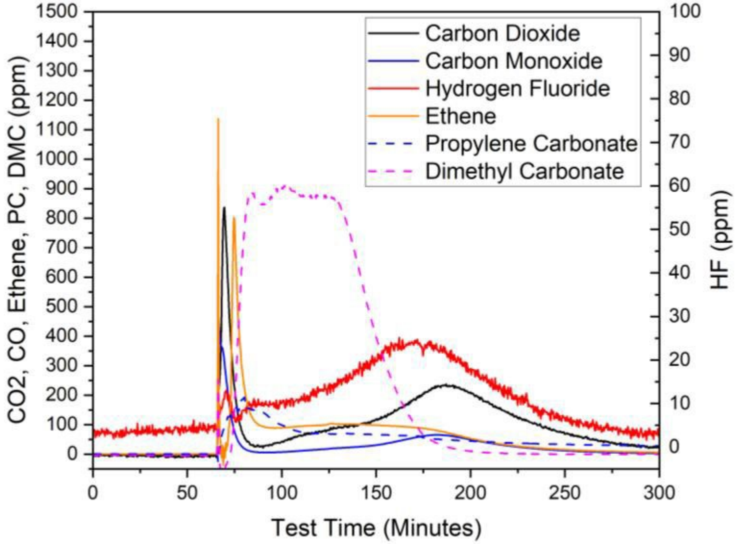
Li-ion 22% SOC





Na-ion 100% SOC





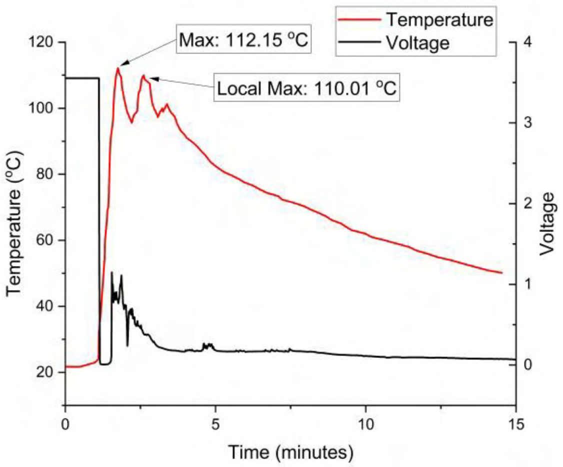
- All monitored gases spike at 64 minutes / 118 °C during TR/venting.
- Solvent species (PC, DMC) dominate gas composition immediately after, while decomposition species (CO, CO_2, HF) increase correlated with continued heating of vented cell.

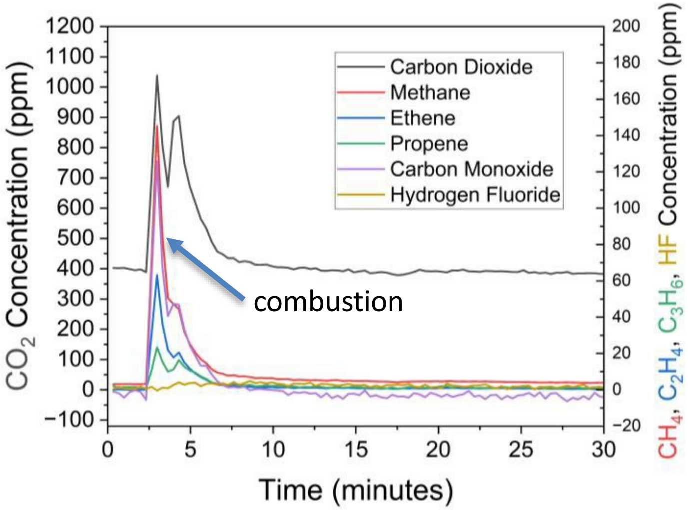
Species	Li-ion 18650		Na-ion 18650	
	Avg. max (ppm)	Calc. vol (mL)	Avg. max (ppm)	Calc. vol (mL)
Carbon Dioxide	1.1E+05	474	1.2E+03	47
Carbon Monoxide	4.2E+04	132	3.5E+02	8.3
Hydrogen Cyanide	1.2E+02	-	-	-
Hydrogen Fluoride	6.2E+02	10	1.4E+01	1.1
Hydrogen Chloride	2.5E+01	-	-	-
Methane	9.6E+03	34	4.5E+02	3.1
Ethene	1.9E+03	-	1.0E+03	-
Propene	1.9E+03	-	1.2E+03	-
Propylene Carbonate	1.6E+02	-	1.6E+02	-
Diethyl Carbonate	2.5E+02	-	3.2E+02	-
Dimethyl Carbonate	7.4E+02	-	9.2E+02	-

- Gases associated with electrolyte decomposition are much lower for Na-ion than Li-ion at equivalent energy density, while solvent vapors are comparable.
- Volumes of gases calculated by using ideal gas law assumptions and flow rate through FTIR exhaust (assumed to be constant but we know it’s not). All values are ~10x lower for Na-ion than Li-ion.

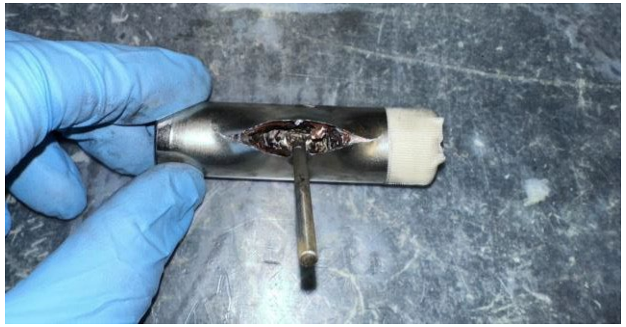
Li-ion 22% SOC

- Loud thud upon penetration.
- Severe sidewall rupture.
- Gas analysis suggests cathode combustion.



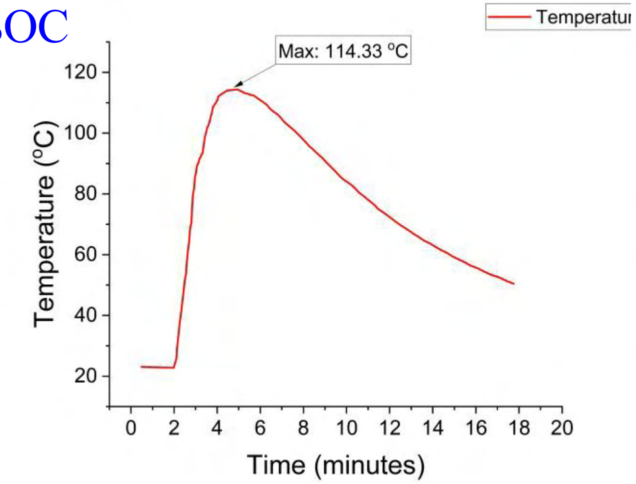


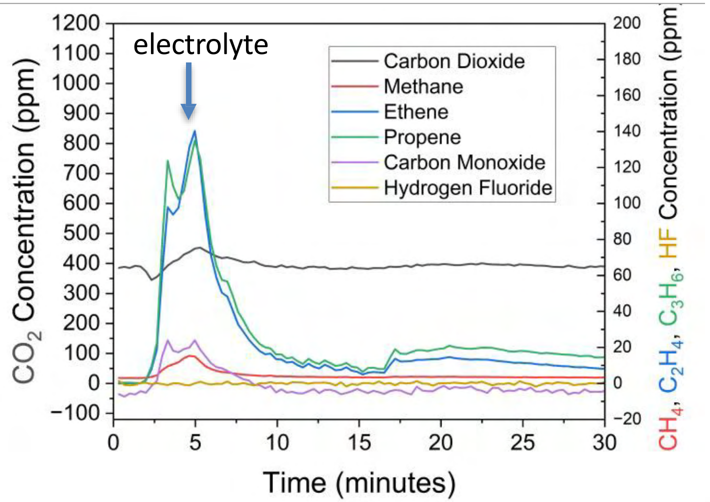
Li-ion 22% SOC



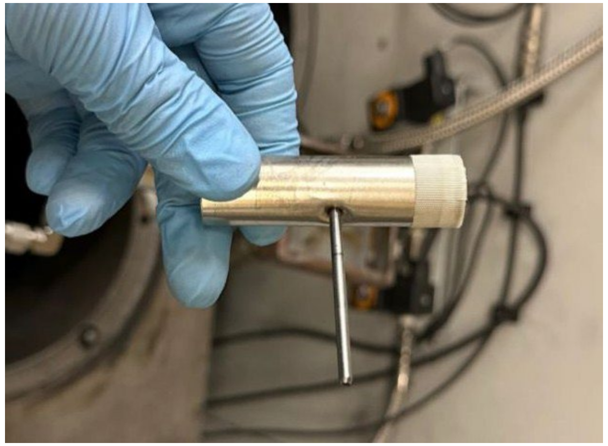
Na-ion 100% SOC

- Self heating observed.
- Gas analysis indicates mostly electrolyte components released.





Na-ion 100% SOC



- Early commercial Na-ion batteries evaluated
    - Promising rate capability
    - Capable of 0V storage
    - Thermal Runaway Risk found to be much lower than Li-ion but energy density is low
- Nail penetration
    - Similar heat rates from each cell
    - Different types of gases detected
- Gas Analysis
    - At least an order of magnitude lower gas production from the 18650 Na-ion compared to low SOC 18650 Li-ion

Next Steps

- Acquire higher energy density Na-ion cells and compare to LFP cells
- Nail penetration of Natron

Rachel Carter
US Naval Research Laboratory
202-404-3360
Rachel.carter@nrl.navy.mil

PHMSA
U.S. Department of Transportation
Pipeline and Hazardous Materials Safety Administration

DOT PHMSA
Mr. Joshua Davis- lead
Dr. Erica Wiener
Mr. Andrew Leyder

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

LI-ION LOCKER

ESSPI

Research, Development and Technology

BLISS (Battery Logistics Integrated Safety System)

November 28, 2023

BLISS - The Project

- USDOT/PHMSA – funded research
- Government/industry partnerships
- Multi-year/multi-phase project
- Specialized battery transport, storage, and charging systems

The Problems

The Problems

New EV batteries burn in a truck on a highway outside of Detroit (2019).
(Photo credit: WJRradio.com)

Felicity Ace burns in the Atlantic Ocean (2022).
(Photo credit: Netralnews.com)

Battery warehouse burns in Morris, Illinois (2021).
(Photo credit: theloadstar.com)

The Problems

- Firefighter entry with limited PPE
- Large explosions in sequence. The move to a defensive posture took too long
- Firefighters told by the owner that they shouldn't use water because there were, "lithium-ion batteries inside"
- How did fire spread?

- Truck explosion/deflagration at Birmingham truck stop
- Massive multi-directional pressure pulse
- Disassembled the trailer box
- Broke the spine of the trailer – rated at 50,000 lbs.
- Limited fire spread

BLISS – The Solutions

The Solutions

BLISS – The Solutions –X Carry Container

Safe Battery Transport, Storage, and Charging Systems

DNOC System
Detection/Notification/Operations/Communications

- Mitigation/Containment
- Monitoring/Detection
- Fire Suppression (large-format)
- Pressure Venting
- Toxic Gas Control
- Audible/Visual Notification
- Global Failure Communications

BLISS – The Solutions – Battery Logistics Trailer

Safe Battery Transport, Storage, and Charging Systems

- Full DNOC system
- Includes active fire suppression, pressure and toxic gas control, and ventilation (EVACS)
- TRL 4
- Ready for extended design and development
- Appropriate for post failure event cleanup

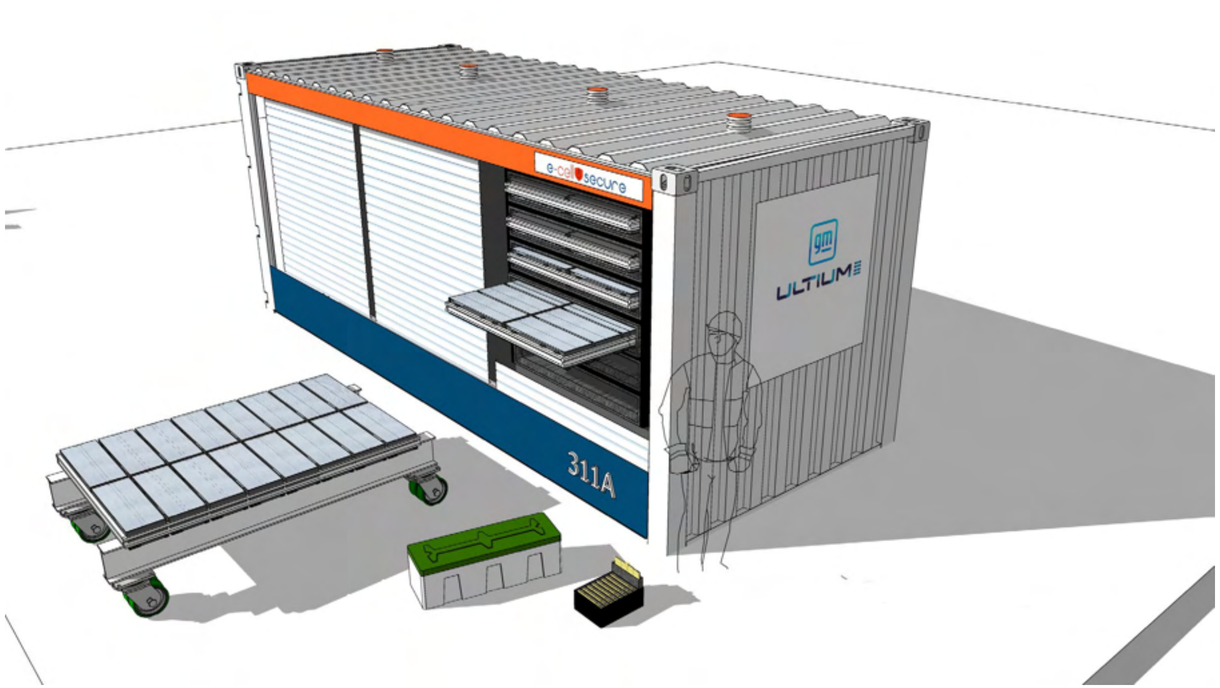
BLISS – The Solutions – Battery Logistics Trailer

Safe Battery Transport, Storage, and Charging Systems

- Prototype displays ability to transport battery packs, containers and 50-gallon drums
- Finished version can be specific to a specific type of container

BLISS – The Solutions – ISO/Conex

Safe Battery Transport, Storage, and Charging Systems



- EV battery pack, module and cell transport and storage
- Closed-loop system can be used for transport and permanent/semi-permanent storage
- Plug-in fire suppression and ventilation capability

BLISS – The Solutions – ISO/Conex

Safe Battery Transport, Storage, and Charging Systems

- E-mobility charging KIOSK
- Designed based on work with NYC and FDNY
- Full DNOC system
- TRL 6
- Provides solution for indoor/outdoor SAFE charging
- Great opportunity for USDOT/PHMSA

BLISS – The Solutions – “Smart Fire Blanket”

Safe Battery Transport, Storage, and Charging Systems

- EV/battery “Smart Fire Blanket”
- Monitors, detects, notifies, and communicates failure
- Blanket function controls fire and off-gassing
- Full DNOC
- TRL 7
- Q1 2024 pilot with 25 companies including GM, Honda, Stellantis, etc.

BLISS – The Solutions – “Smart Drum”

Safe Battery Transport, Storage, and Charging Systems

- EV/battery “Smart Drum”
- Monitors, detects, notifies, and communicates failure
- Specialized CAP and lid unit
- Full DNOC
- TRL 7
- Q1 2024 pilot with 15 companies including GM, Honda, Stellantis, etc.

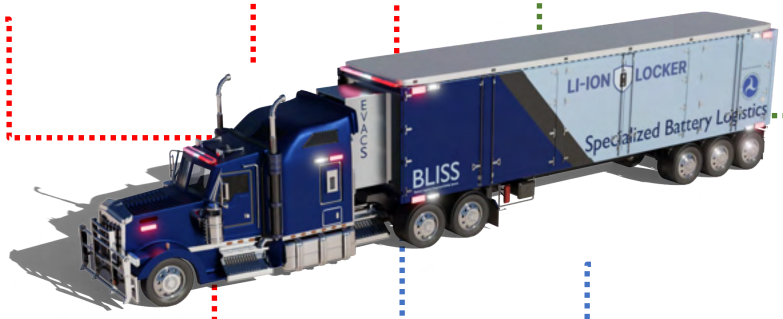
BLISS – The Solutions – “Smart Fire Blanket”

Detection/notification
- Electronic detection
- Audible and visual alarms

Higher risk reduction
- Controls internal failure
- Prevents propagation
- Smart venting system

Cost-efficient
- Reusable containers
- Profit for bike shops
- Insurance reductions

Failure containment
- Fire/propagation control
- Toxic gas neutralization



City solutions
- Aligns with current cityscapes
- Non-disruptive

24/7 monitoring
- Continuous failure monitoring

Sustainable metrics
- Charging
- Battery recycling
- Swapping center

Scalable system design
- Designed for a range of battery sizes and chemistries

BLISS Burn Testing Detroit Fire Department

BLISS – Thank You

Safe Battery Transport, Storage, and Charging Systems

Thank You

contact:
ron@esspi.com

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

Research, Development and Technology

In-Field Magnetometry for Determination of LiB SOC and SOH

Dr. Joshua R. Biller

November 28, 2023

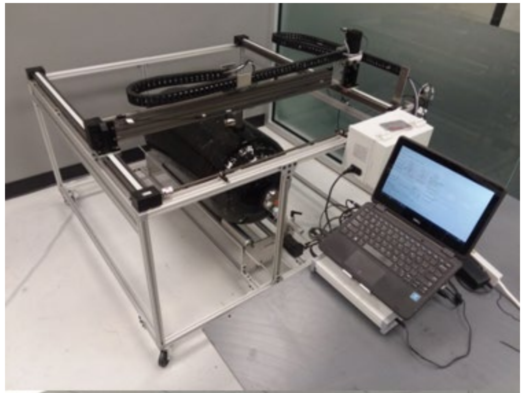
Housekeeping

Information relayed in this presentation is covered by:

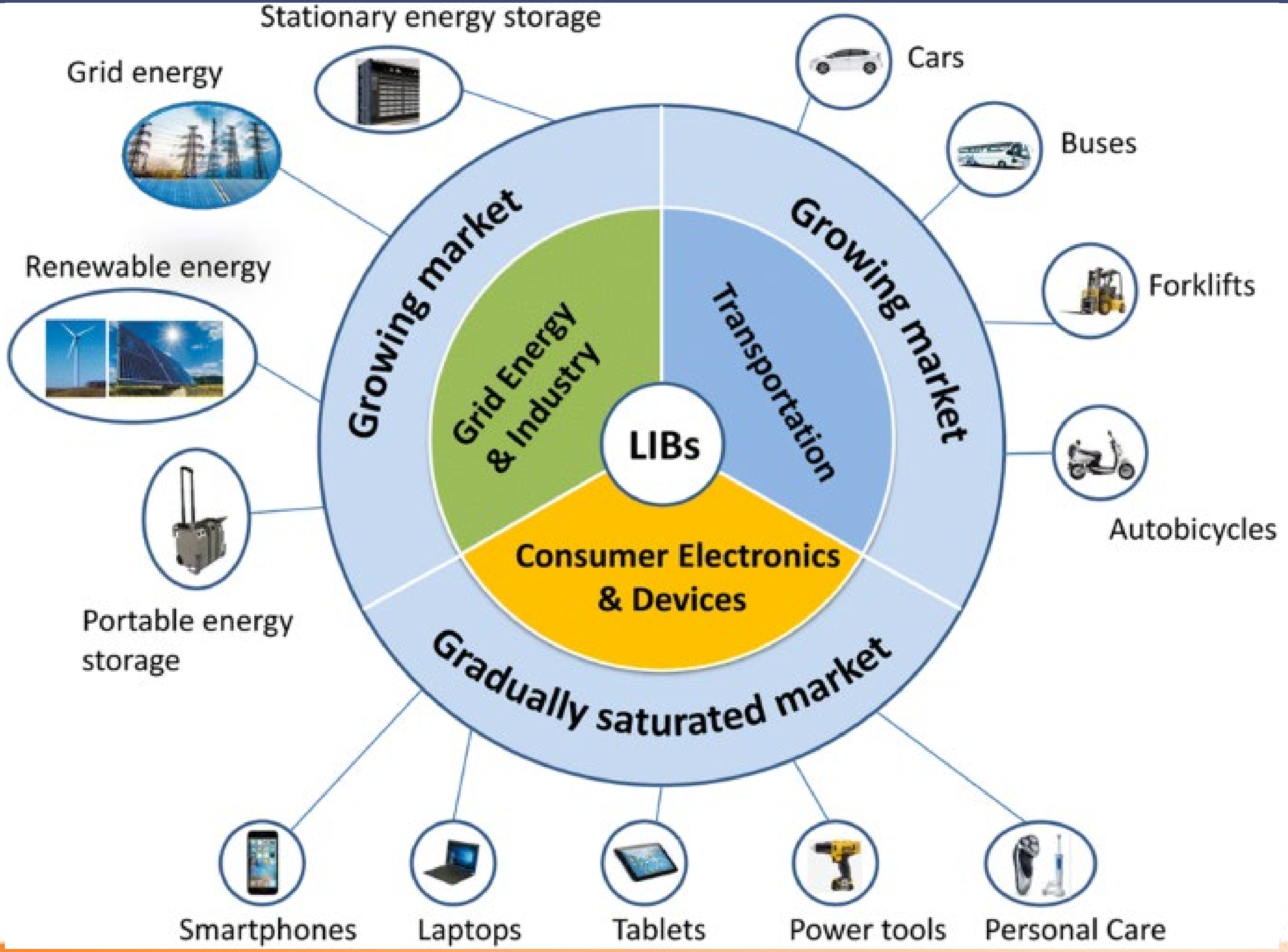
- SBIR Data Rights under DOT 6913G623P800063
- Patents pending with USPTO
    - Provisional #63/338,710 “Non-Contact Method for Non-Destructive Evaluation of Lithium Ion Batteries with Optically Pumped Magnetometer”, filed 05/05/2022
    - Non-provisional #18/144,122 “Non-Destructive Evaluation of Lithium Ion Batteries”, filed 05/05/2023

About TDA Research Inc.

- **In Business for 36 years**
  - Privately held—8 partners, all active in daily operations
  - ~130 employees, 33 Ph.D.'s chemistry/engineering
  - Over $28 million in annual revenue
- **Facilities**
  - Combined 75,000 ft^2 laboratory and office space near Denver, Colorado
    - Synthetic Chemistry
    - Materials Testing
    - Defense & Aerospace
    - Sensor Technologies

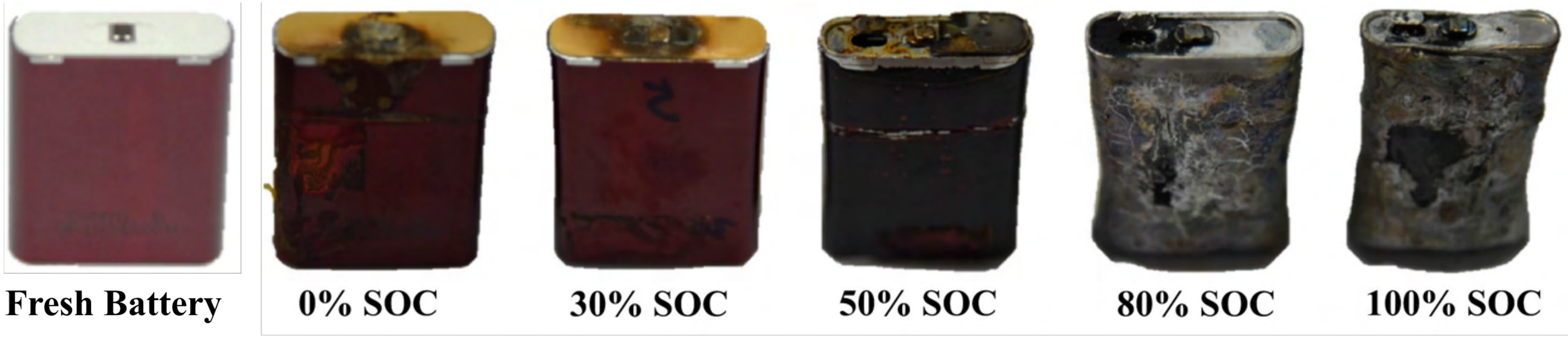


Lithium-Ion Batteries (LiB)



https://evolt.aevt.org/news/view/11

Problem or Opportunity



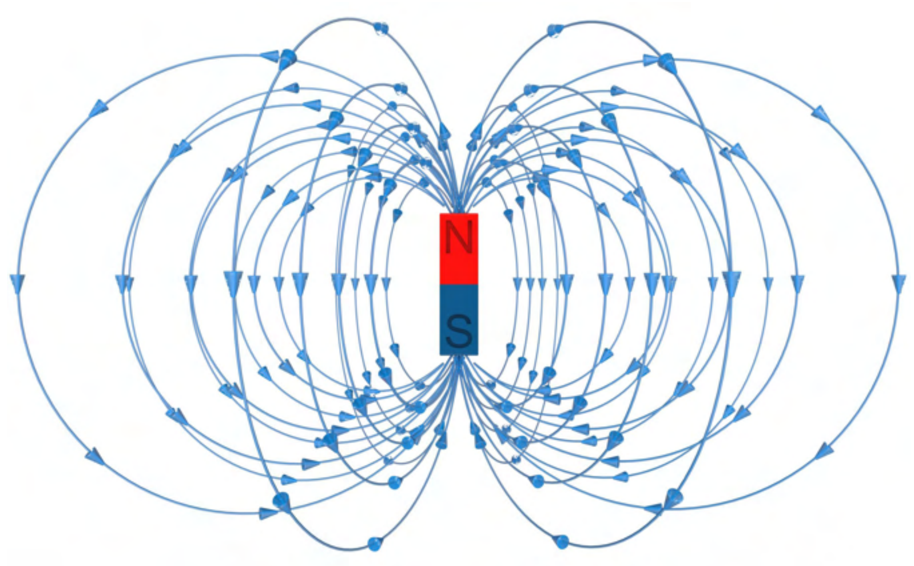
He, X.; Hu, Z.; Restuccia, F.; Fang, J.; Rein, G., Applied Thermal Engineering 2022, 212, 118621.

No currently available non-contact and non-destructive evaluation (NDE) techniques for SOC or health monitoring of LiBs

- Shipment: Evaluate SOC or health prior to or during shipment
- First-Responders: Evaluate the likelihood of thermal runaway occurring at crash site

A LiB as an Inadvertent Magnet

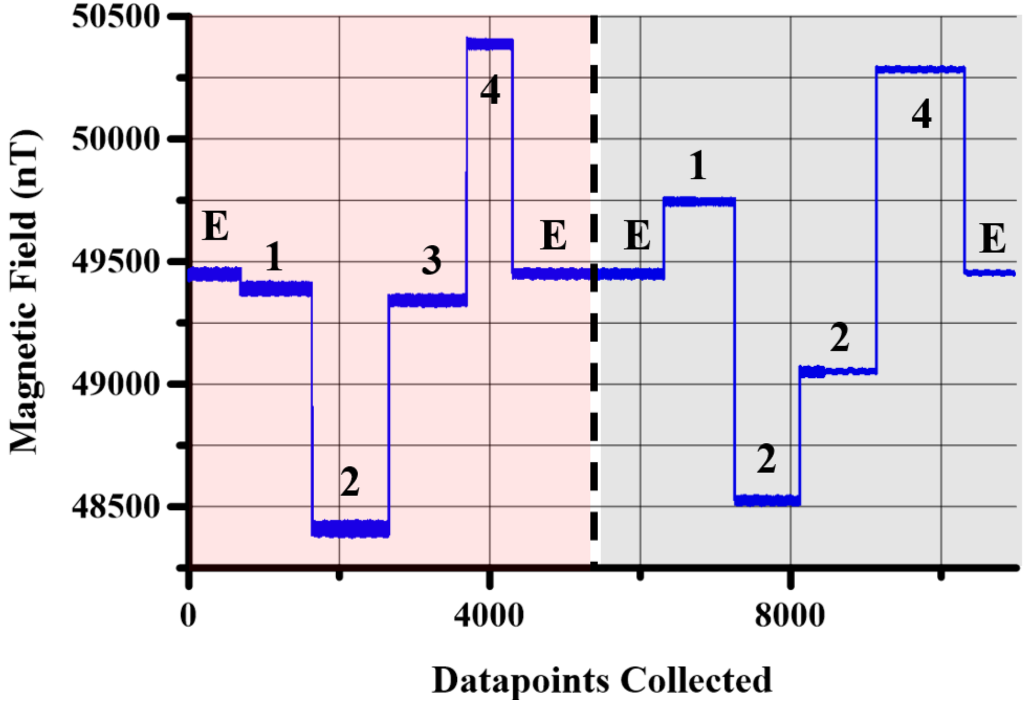
Q: What are the overlapping characteristics of a bar magnet and a 18650 LiB?



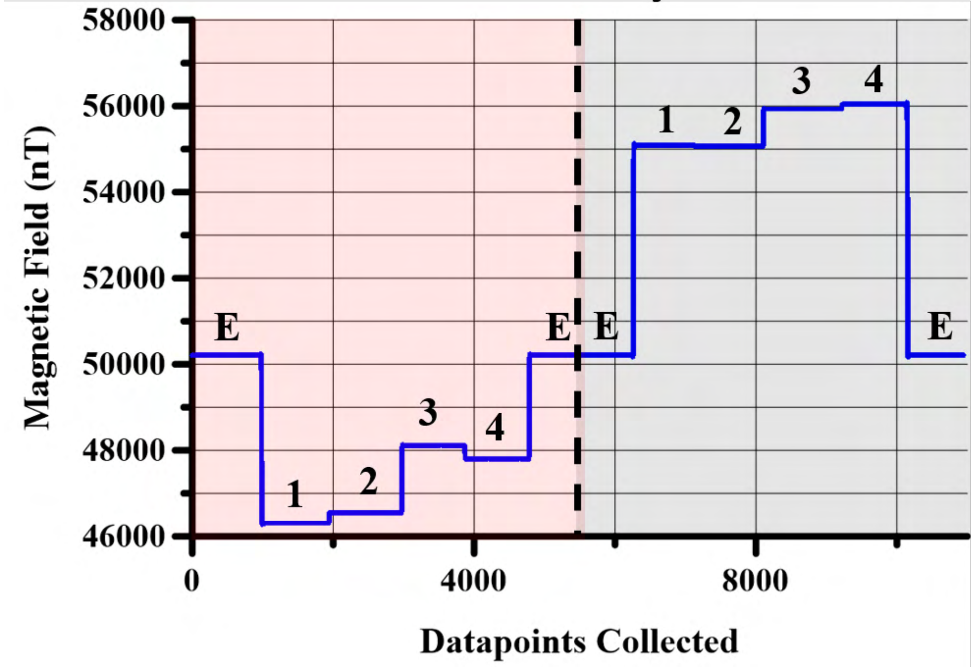
A: Arrangement of microstructural ferromagnetic units determine a macro-scale magnetism

Air Force Study - 18650 LFP

“Fresh”



After 50 Cycles

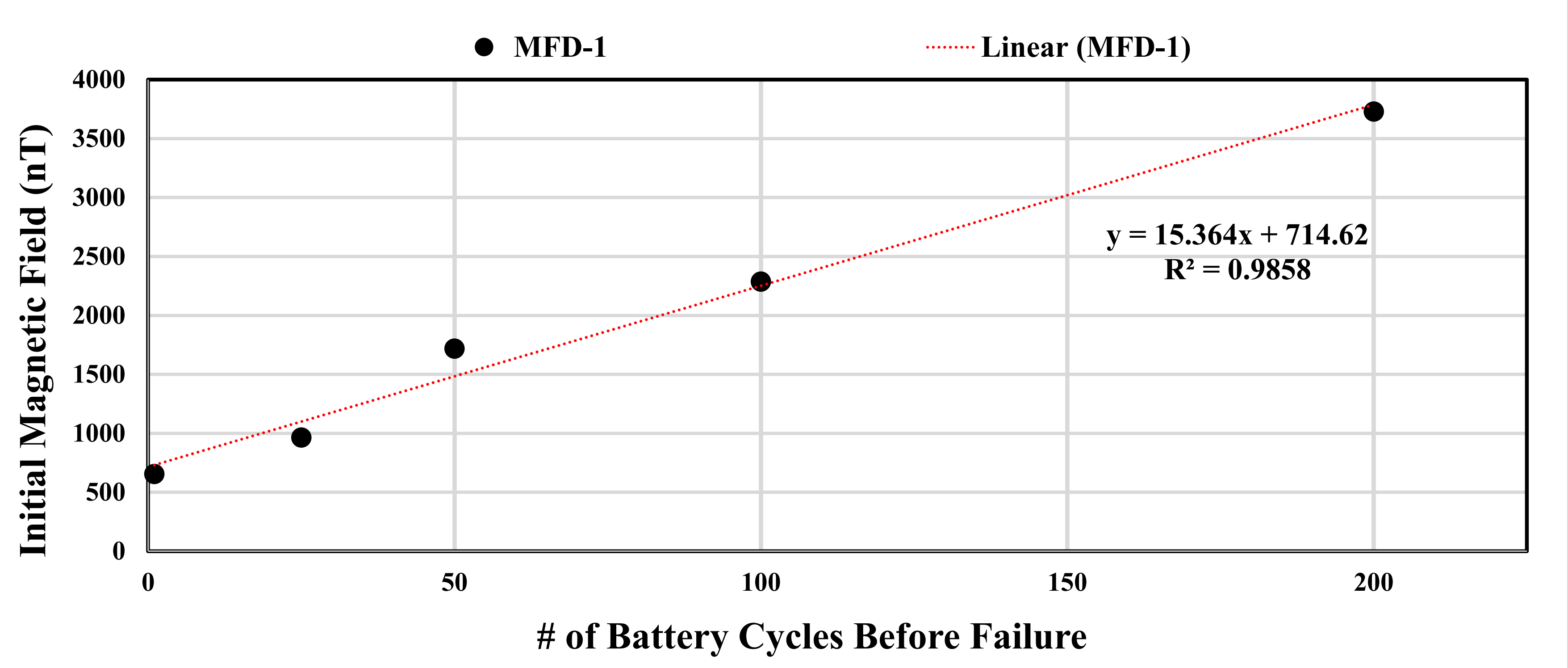


The magnetic field around a lithium ion battery is <u>anisotropic</u>, and <u>changes</u> as a function of accelerated lifetime.

AF FA8649-20-P-0968

Air Force Study - 18650 LFP

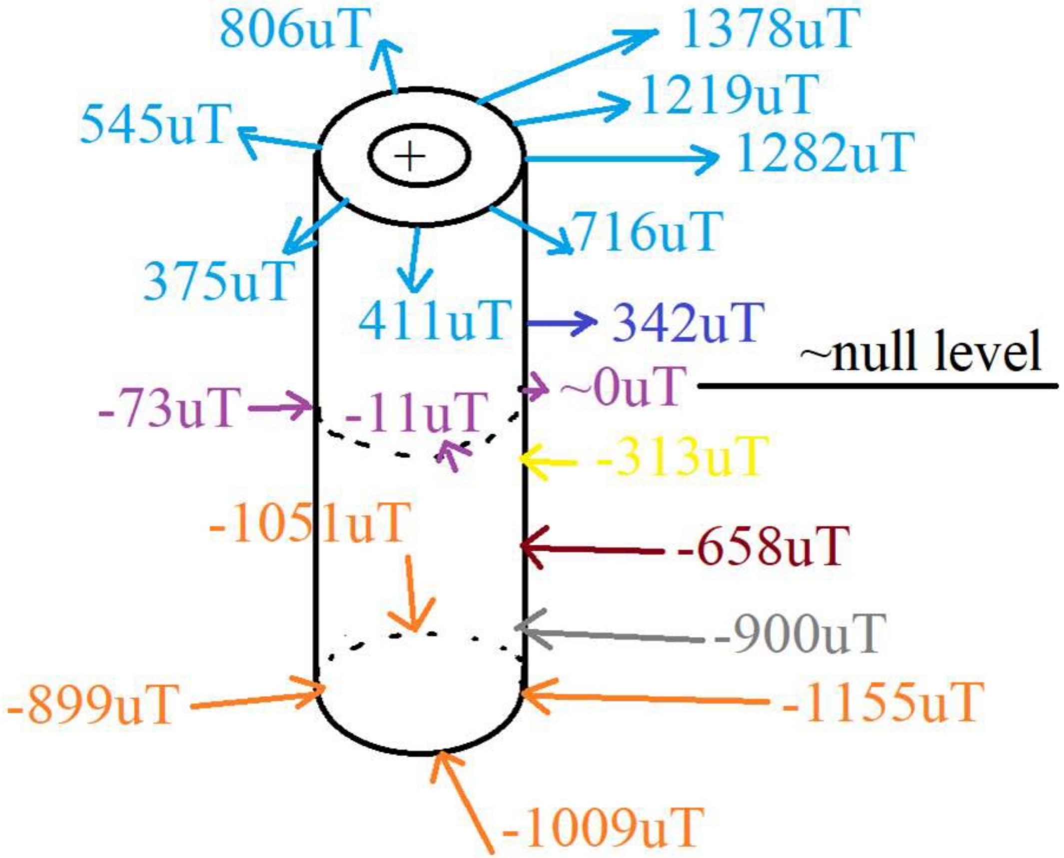
AF FA8649-20-P-0968



"Failure" = capacity fade ≤ 80%

In one case (LFP), a larger starting magnetic field signature correlated with longer cycling until 80% capacity fade was reached

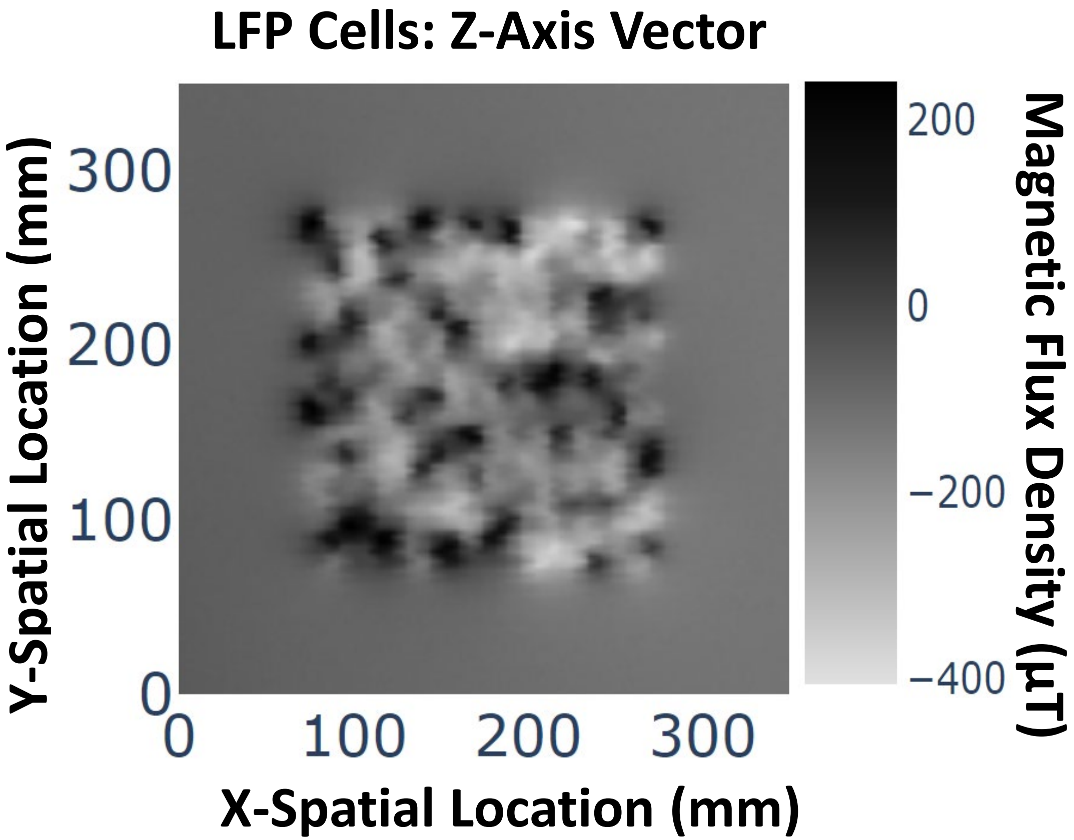
DOT Work - NCA 18650



Visualizing the 3D, anisotropic magnetic field of a NCA 18650 battery

6913G623P800063

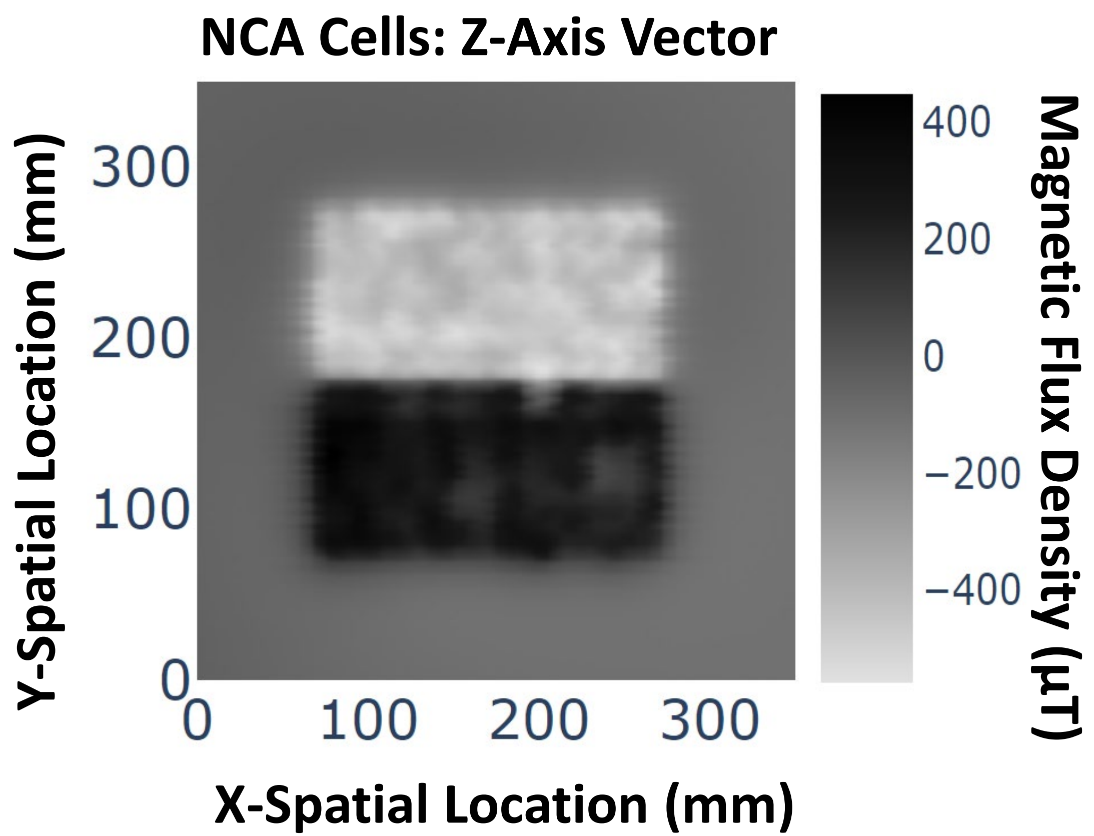
Magnetic Map of 100 - 18650 LFP

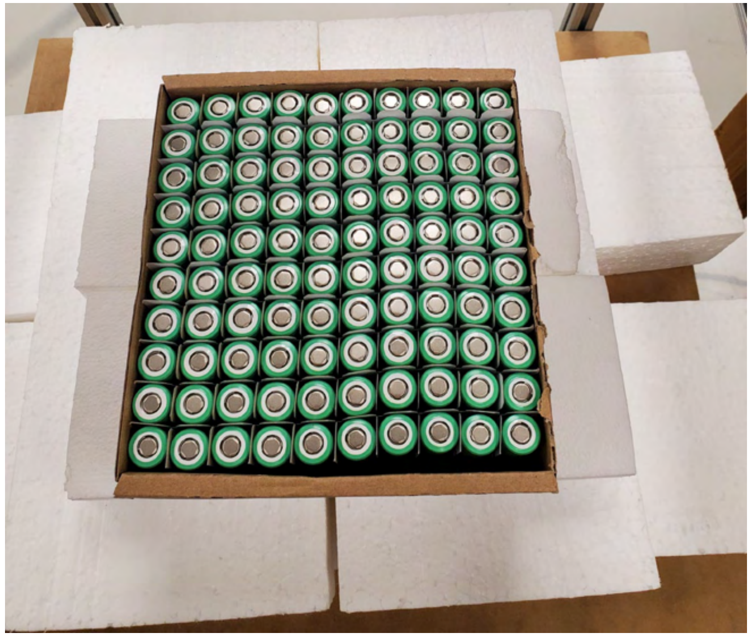


The magnetic field (Z-direction) of 100 LFP 1850 collected in ~30 minutes

6913G623P800063

Magnetic Map of 100 - 18650 NCA

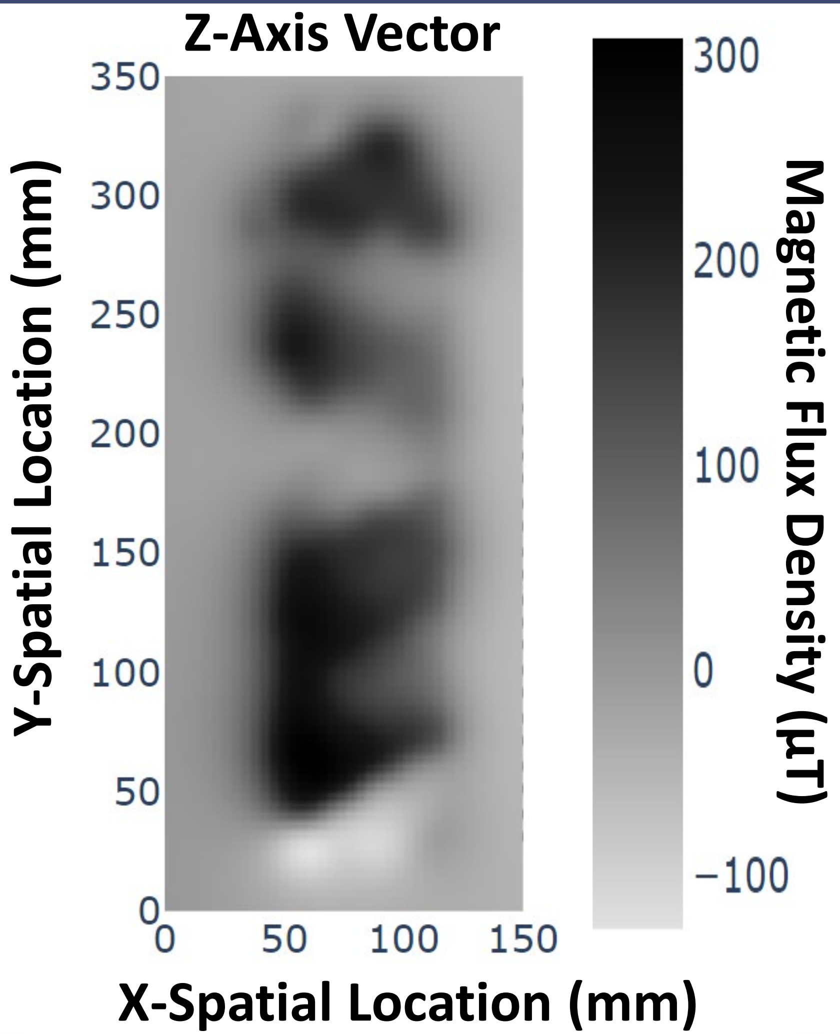




The magnetic field (Z-direction) of 100 NCA 1850 collected in ~30 minutes

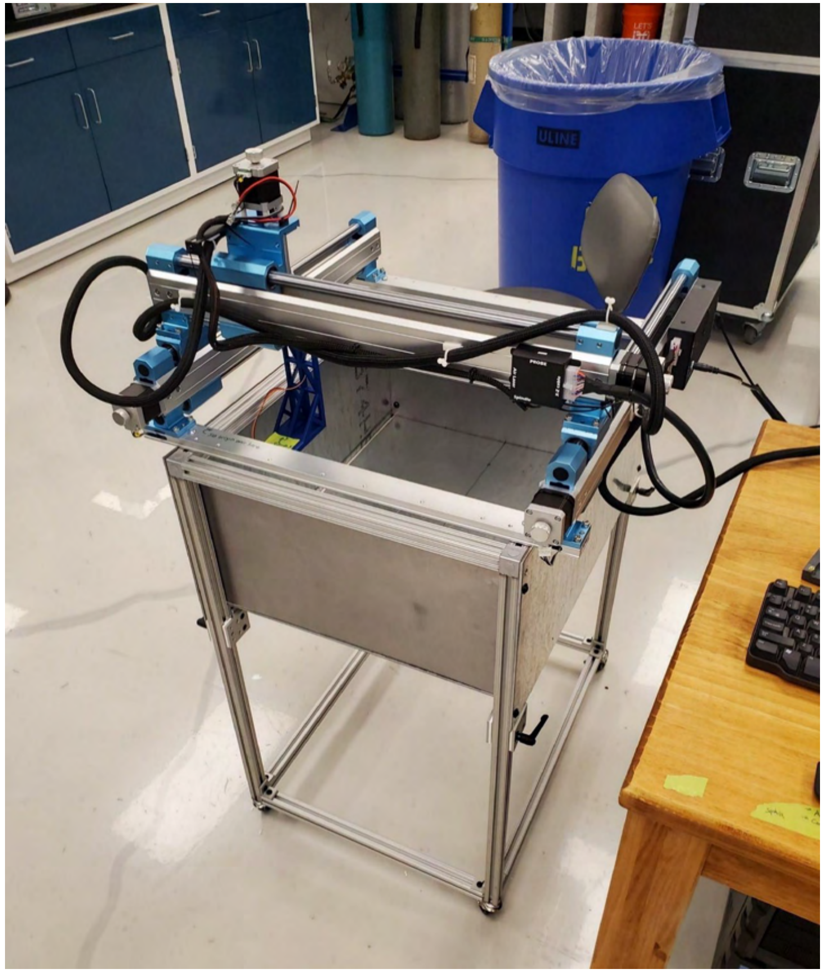
6913G623P800063

E-Bike Battery

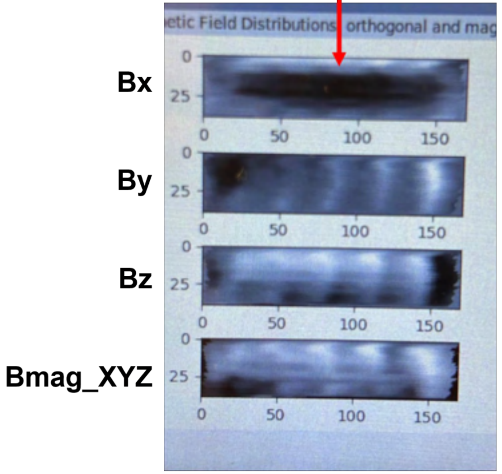


The magnetic field (Z-direction) of 100 a commercial E-bike battery shows this information can still be collected in 18650 "packs"

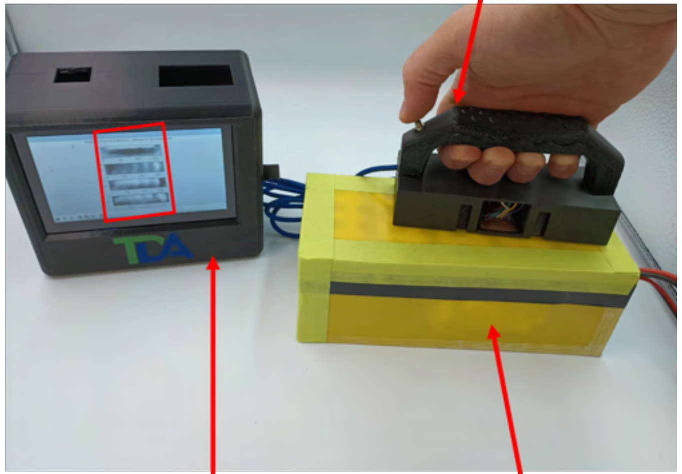
Lab to In-Field



10Ah, 36V battery scans made with TDA's prototype



3rd Gen Scanner



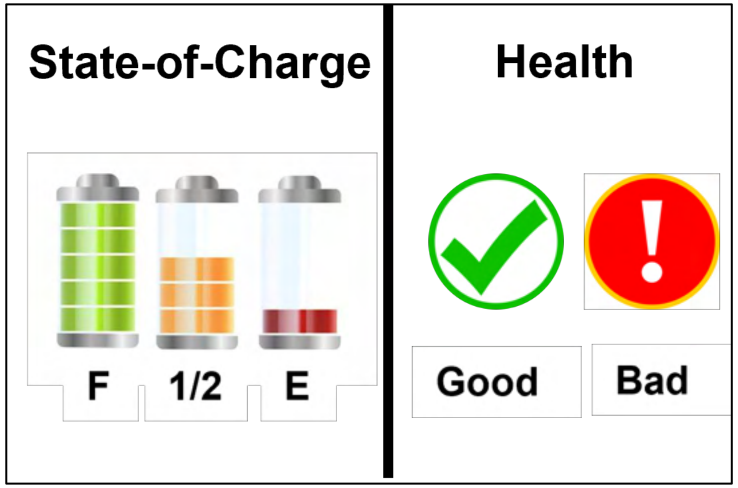
Fully Integrated Raspberry Pi 4 and 5" LCD Display

10Ah, 36V Battery

TDA has developed prototypes for lab and in-field magnetometry scanning of batteries and/or packs

Summary

- **LiB as an "inadvertent" magnet**
  - Cathode chemistries – LCO, LFP, NCA
  - 18650 geometries
  - Singles, multiple open potential, multiple in series for larger battery pack
- **Calibrating magnetic field signature with electrochemical characteristics**
  - SOC – NCA, LFP
  - SOH – LFP
- **Current Efforts –**
  - Magnetic field change in full battery pack while energized
  - Interpretation of "bulk magnetic field" of a collection of 18650 to enhance throughput for SOC & SOH screening



Contact Information

jbiller@tda.com

DOT #6913G623P800063
Mr. Joshua Davis, PM
Mr. Jorg Kaltenegger
Dr. Michael Klem

Brad Spatafore, MS
Mechanical Engineering
In-Field Device Design

Kevin Finch, PhD
(Analytical Chemistry)
Integrate data collection and software design

David Long, EE, ME
Circuit board design and construction
Precision machining
Support with data collection and software design

Pipeline and Hazardous Materials Safety Administration

Office of Hazardous Materials Safety

2023 Research, Development and Technology Forum

Andy Leyder

November 28, 2023

OHMS RD&T Future Research Initiatives & Program Priorities

Future Research Initiatives

Exploring Potential Rail Research Projects

Potential Research Area #1

Evaluate Tank Car Safety Materials & Coatings

Potential Research Area # 2

Performing Risk Assessments & Identifying Prevention & Mitigation Strategies

Potential Research Area # 3

Performance Validation on Tank Car Instruments

Future Research Initiatives

Climate Change and Sustainability Research

Researching Recycled Plastics used for hazardous material packaging

Assessing the risk & mitigation methods with transporting Hydrogen and CO_2

Pinpointing innovative and emerging technology to address climate change.

Future Research Initiatives

Lithium-ion Batteries & Next Generation Batteries

Continue assessing evolving challenges with transporting lithium-ion batteries.

Identifying and Researching emerging battery chemistries and technologies.

Detecting novel and emerging methods to transport lithium-ion batteries.

Future Research Initiatives

Emerging Technology

Seeking cutting edge technology and materials for packaging

Engaging with Federal Partners on Autonomous Vehicle Research

Researching the use of Predictive Analytics and Sensing Technologies.

Program Priorities

RD&T Research Program

Small Business Innovation Research (SBIR) Program

- Continue working with our existing Small Business.
- Prepare for FY 24 SBIR solicitation.
- Continue to seek out SBIR topics

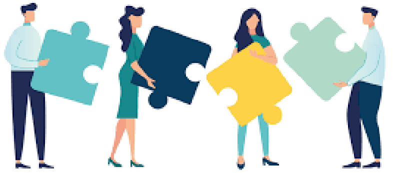
SBIR · STTR
America's Seed Fund™
POWERED BY SBA

Federal Partners

- Continue to collaborate with existing partnership with our federal partners.
- Foster new collaboration efforts with other federal partners.

Subject Matter Expert Research

- Engage with internal and external SMEs on research topics.
- Identify potential new research projects driven by SMEs.



Program Priorities

Stakeholder Outreach & Engagement

- Communicate Research Results Out to Stakeholders
- Engage with MSI & Academica Institutions
- Continue to Identify New Stakeholders
- Increase RD&T Visibility and Brand
- Develop Engagement Tools and Materials
- Identify Research Consortiums to Participate In

OHMS RD&T

Questions?

Contact Information

Yolanda Y. Braxton
OHMS Operations Systems, Director
Email: yolanda.braxton@dot.gov

Andrew "Andy" Leyder
OHMS Research, Development & Technology, Acting Chief
Email: andrew.leyder@dot.gov